THE

MINING INDUSTRY OF JAPAN

DURING THE LAST TWENTY FIVE YEARS.

1867—1892.

BY

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JAPAN.

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EQUIVALENTS OF WEIGHTS AND MEASURES.

SCALE—1 *shaku*, 10 *sun*, 100 *bu*, 1000 *rin*	=	0.30303 metre	or	0.9964 ft.
WEIGHT— 1 *kwamme*, 1000 *momme*	=	3750 grammes	or	119.9328 oz.
1 *momme*	=	3.75 „	or	0.1199 „
1 *kin*, 160 *me* or *momme*	=	600 „	or	19.1840 „
MEASURE—1 *koku*, 10 *to*, 100 *sho*, 1000 *go*	=	180.39068 litres	or	381.1653378 American pints. 19008.6971462 cubic inches.
SQUARE MEASURE—1 *tsubo*, 6 feet × 6 feet	=	36 square feet.		
MONEY—1 *yen*, 100 *sen*	=	$ 1.00.		

WOOD MEASURE—1 *tana*, used for fire-wood measure at mines. It is different at different mines, at one place it is 10 × 10 × 2.6 feet and at others 5 or 6 × 5 × 2 or 2.5 feet.

ERRATA.

Page 1, line 13, from bottom for "nineth" read "ninth."
„ 3, „ 4, „ „ „ "Geological Maps" read "Mining Surveys."
„ 20, „ 14, „ top for "Caniozoic" read "Cainozoic."
„ „ „ 6, „ bottom for "The latter" read "In Japan."
„ „ „ 4, „ „ after "view" insert "the other."
„ „ „ 4, „ „ for "former" read "younger."
„ 21, „ 1, „ top for "prophyrite-like" read "porphyrite-like."
„ „ „ 13, „ „ after "country" insert "may."
„ 22, „ 5, „ „ for "hief" read "chief."
„ „ „ 8, „ „ „ "latter" read "lowest series."
„ 24, „ 15, „ „ „ "earlier" read "younger."
„ 25, „ 18, „ „ „ "Volcano" read "Volcanic."
„ 27, „ 15, „ bottom for "vien" read "vein."
„ 28, „ 1 & 2, from bottom after "and" omit "as the"
„ 31, „ 2, from bottom for "earlier" read "younger."
„ 32, „ 14, „ top for "Psendo-monotis" read "Pseudomonotis."
„ „ „ 12, „ bottom for "Kaisho-gneiss" read "Kashio-gneiss."
„ „ „ 11, „ „ „ "Granite-greiss" read "Granite-gneiss."
„ „ „ 5, „ „ „ "earlier" read "younger."
„ 35, „ 14, „ top after "in" insert "those."
„ 36, „ 7, „ „ for "steep" read "step."
„ „ „ 4, „ bottom for "These" read "There."
„ 38, „ 7, „ top for "earlier" read "younger."
„ 41, „ 3, „ „ „ "only excepting" read "with the exception of."
„ „ „ „ „ „ after "Tsurushi" insert "others."
„ 52, „ 14, „ bottom after "called" insert "the."
„ „ „ „ „ „ „ "Kaseibi" insert "is."
„ „ „ 7, „ „ for "cut" read "cuts."
„ 61, „ 19, „ top after "are" insert "argentite."
„ „ „ „ „ „ for "myargyntite" read "ruby silver."
„ „ „ 18, „ „ „ "vein stuffs are" read "vein stuff is."
„ „ „ „ „ „ „ "feld spar" read "rhodochrosite."
„ 66–67, Dressed Ore .... 7,811,377.2000 *kwamme.*
Stamped Ore .... 7,240,267.1000 „
Silver Amalgam .... 19,065.6800 „
Amalgamation Residue .... 4,997,678.1000 „
Concentrated Ore .... 1,484,707.1000 „
Vanned Ore .... 51,341.0000 „
Roasted Ore .... 4,006 804.3000 „
Precipitation Process Material .... 4,006,804.3000 „
Precipitated Silver .... 1,793.5852 „
Matte from Smelting Furnaces .... 71,462.4000 „
Cupelled Silver .... 544 6450 „
Refined Gold .... 13.8066 „
Refined Silver .... 3,230.8093 „

Page 73, line 1, from top for "structure" read "formation."
" " " 4, " " after "conglomerate" omit "and."
" " " " " " " "breccia" omit "formed of."
" " " 5, " " for "augite, and" read "and augite."
" 90, " 3, " bottom for "quartz" read "liparite."
" 91, " 11, " top for "it is" read "they are."
" " " " " " " "looking like hornblende" read "look like."
" 112, " 12, " bottom for "porphyrite" read "propylite."
" " " 6, " " after "oxide" insert "of."
" 122, " 4, " top for "containing" read "and."
" 137, " 3, " " " "andesite of Tertiary age" read "Tertiary rocks and andesites."
" 168, " 10, " " " "mica" read "a crystalline."
" " " " " " omit "crystalline hornblende, quartz, serpentine and other rocks are also often found."

Page 168, line 13, from top for "vein" read "bed."
" 177, " 3, " bottom for "bed" read "sheet."
" " " 2, " " " "formed" read "injected."
" 183, " 13, " top for "tetrahedrite and bornite" read "and tetrahedrite."
" 187, " 3, " bottom after "are" omit "volcanic."
" " " 3, " " after "to" insert "the."
" " " 3 & 4, " " omit "colour reddish brown; strike north 10°–20° N.W. The hardness and density of these rocks vary in different places."

Page 202, line 16, from top after "crystalline" insert "gneiss."
" " " 17, " " for "strata" read "sheets."
" 215, " 4, " bottom for "Era" read "and Tertiary eras respectively."
" " " " " after "the" insert "bed of."
" 218, " 6, " top omit "in Yamato."
" " " 10, " " " "schalstein" read "chlorite schist."
" " " 14, " " " "form" read "that of."
" " " 17, " " after "copper pyrites" insert "and iron pyrites."
" 224, " 14, " " for "all the ore is known to be very rich and has the most splendid crystals of stibnite in Japan" read "The ore which is stibnite occurs in splendid crystals."

Page 224, line 15 & 16, from top for "although they are formed" read "Although they are found.
" 231, " 13, from top for "Ttransportation" read "Transportation."
" 262, " 5, " bottom for "Geology and Chemistry give a similar description of this mine as that of" read "Geologically and chemically the coal at this mine is similar to that at."

Page 274, line 8, from bottom for "it" read "the rock of the mine."

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CONTENTS.

A HISTORY OF MINING INDUSTRY IN JAPAN.

One of the causes, as is generally known, that led Columbus to the discovery of America, was his desire to obtain precious metals from Zipangu or Japan, which he had read about in the writings of Marco Polo. It follows from this that the name of the famous discoverer is directly connected with the mines of Japan.

The history of mining in Japan dates from between the end of the seventh and the beginning of the eighth century, when, though on an extremely small scale, gold, silver, copper, tin, iron, cinnabar, coal, petroleum, and other mineral substances commenced to be mined. Prior to that time all the metals seem to have been imported from China and Corea. The first years of the nineth century showed a considerable progress in mining industry. It was then that the Tada silver mine, Ikuno gold mine, Yoshioka copper mine, Handa silver mine, Osaruzawa copper mine, Hosokura silver and lead mine and others which are still working and as prosperous as ever, were first opened.

The mineral wealth of this country as now known is something enormous. The coal in Hokkaido and Kiushu, antimony in Shikoku and Kiushu, and gold, silver, copper, and iron in these and other provinces, seem almost inexhaustible. Copper, which has been produced in immense quantities from ancient times ranks first, gold and silver stand next, while coal, antimony, manganese, and sulphur, which are now being exported, follow.

Mining prior to the Restoration:—In this period the art was merely empirical, but what might be done without the aid of science seems to have been carried to the utmost extremity.

I. Mining.

Mining was always commenced at the outcrop and the lode followed as it ran. No implements larger than picks, small drills, and hammers were used and only the softer bonanzas could be worked. The pits excavated were only sufficiently wide to allow the miners to sit in on their straw seats, and ran zigzag and undulating so that they had often to walk on all fours. The pit mouths were usually in dales or on hillsides. The drifts being narrow, timbering was seldom required and where used, it was no more than a horizontal stull raised on two posts. For transportation, boys were invariably employed, who carried the ores in small bamboo or straw baskets. Ventilation was by no means good and it was not infrequent that the lamps went out of themselves. The only means of ventilation then known was to have one narrow drift over another made to communicate with each other by boring through the floor of the upper level at intervals of several yards. Where bamboo torches were in use, ventilation was especially bad and winzes had to be excavated. In mines, where water occurred in large quantities, water levels were sometimes excavated, the ordinary means of drainage being the use of rude inefficient pumps of wood or bamboo with single valves at their lower ends. In consequence of this in nine cases out of ten mines became unworkable in consequence of floods.

Imperfect as the mining methods were, excavations were often carried to distances of from four to seven hundred feet and much to our wonder and astonishment, drainage levels were driven a number of miles. The levels were made with moderate gradients, not necessitating the use of ladders, the only thing of the kind used being notched logs.

II. Dressing.

The ores were first crushed with iron hammers by which much of the veinstuff was removed. They were further concentrated by means of bamboo baskets, each about two feet diameter, and "*Yuri-ita*" round concave boards. The gold and silver ores were ground in stone mortars and afterwards treated on the inclined "*neko*" or "*nekonagashi*." These primative methods undoubtedly resulted in a considerable loss of valuable ores.

III. Metallurgy.

The gold, silver, copper, and lead ores were all treated much in the same way, i.e. the dressed ores were first roasted in stone hearths, after which the roasted materials were mixed with certain proportions of charcoal, and then smelted in ground hearths which were flat, round, concave, each 1 foot diameter and some 1.3 feet deep. For blowers nothing better than wooden bellows were employed.

The gold and silver ores had suitable quantities of lead added, while smelting them in order to prepare them for a process termed "*nambanbuki*," a kind of liquation. In carrying out this rude form of liquation, green sticks were used as stirrers. Nothing was done to prevent the necessary loss of small portions of precious metals through volatilization and being carried along with the slag.

These methods of dressing and metallurgy, simple and handy as they were, were on too small a scale for profitable working of ores in large quantity.

What deserves especial notice as manifesting a condsiderable degree of advancement in this period are:

1. The making of Geological maps, of which the Sado mine has excellent examples. These give the precise course and dip of each vein and the number, directions, and dimensions of the levels and winzes with considerable

accuracy, although the only instruments used in surveying were brass compasses with their circles divided from right to left into twelve equal parts, each subdivided into thirty degrees and ropes and poles marked with *ken*, *shaku*, *sun*, and *bu*.

2. The use of a peculiar hydraulic ram the excellent construction of which is certainly remarkable. This was found in a buried pit of the Sado mine.
3. The use of stamping mills and octagonal trommels propelled by water-wheels. These were used in mines conveniently situated for the utilization of hydraulic power.
4. The separation of gold and silver from copper by the "*nambanbuki*" process.
5. The separation of silver from gold by fusing them with sulphur.

Mining as Practiced after the Restoration, i.e. during last Twenty-five years:—This period commences with the introduction of the art of blasting and the use of gunpowder. It may be subdivided into three epochs:—

1. The epoch of the introduction of foreign arts and machinery.
2. The epoch of imitation.
3. The present epoch.

I. The Epoch of the Introduction of Foreign Arts and Machinery:

Towards the end of the Tokugawa period of Japanese history, mining was at the lowest ebb of prosperity, when through Viscount Inouye Masaru, Mr. Erasmus Gower, an Englishman, was employed by the Shogunate government to direct the working of the Sado mine. Here he introduced blasting. About this time Pumpelly, an American Engineer, also used gunpowder at the Yurap lead mine in Yesso. Mr. Gower was also employed at the Kayanuma (Iwanai) coal mine.

At the Restoration the new government employed Mr. Coigny, a French engineer, and sent him to the Ikuno gold and silver mine. It was intended to use these mines as models for imitation. Mr. J. G. H. Godfrey, an Englisman, was appointed Chief Engineer and entrusted with the supervision of all government mines. An engineering college was established and Mr. H. Dyer was engaged as director and Mr. John Milne as professor of mining. In 1867 a pit was sunk on Takashima by Mr. S. Morris. Following Mr. Morris came Messrs. Waters, Braedemeyer and Potter. Subsequently when this mine, which has been the most important coal mine in the country, passed into the hands of the government, Mr. Potter took charge of the Miike coal mine while Takashima was in charge, first, of Mr. H. W. Martin and then of Mr. John Stoddart. In addition to the se Engineers others were employed, amongst whom we mention Messrs Lyman, Reh, Gojot, Frechville, and several others. Now there are no European mining engineers at our mines. The results attained during this epoch were:

a. At Sado and Ikuno Mines.

1. Overhand and the underhand stoping was practiced.
2. Timbering improved, using stones or brick where permanency was desired.
3. Assaying based on scientific principles was introduced.
4. Crushing, concentrating, and classifying machines introduced.
5. Reverberatory and blast furnaces constructed.
6. Amalgamation and precipitation processes adopted.

b. At Takashima and Miike Collieries.

1. Boring machines employed.
2. Post and stall and long wall systems adopted.
3. Sinking shafts and building engine inclines, provided with winding engines.

4. Fans used for ventilation.
5. Pumps used for pumping up water from underground.
6. Trucks and railways were introduced.

In these and other mines, among the rest, the Okudzu gold mine, Kamaishi iron mine, Innai and Kosaka silver mines and Ani copper mine, levels were driven, railways constructed, tubs and winding and drawing machines adopted, hydraulic, animal and steam powers utilized for machines of different kinds, and foreign engineers as many as twenty in all, among whom there was the German engineer, Curt Netto, who directed the Kosaka mine, were employed.

This period, which lasted for ten years, wrought quite a revolution in our mining arts. In consequence of the immensity of the sums spent and in a few cases through the carrying out of mistaken designs, although much benefit was derived here and there, money was lost.

II. The Epoch of Imitation :

The government mines thus improved became objects for imitation. The private mines throughout the Empire commenced to adopt the more easily imitable methods of foreign style, among others the art of blasting, which not one mine in the whole country failed to take advantage of. The Handa mine had its metallurgy remodelled in complete imitation of the Ikuno mine and the result was remarkably good.

By this time the improved arts were almost ripe for yielding their natural fruits, but the lack of experience on the part of native engineers and the returning home of most foreign engineers employed, retarded their fruition for some years.

Private mines, where imitation was too often blind mimicry, often failed to reap the desired success, their engineers being mostly men of mere experience and with but little scientific knowledge.

The Ashio copper mine of Mr. Furukawa Ichibei showed a remarkable degree of prosperity and did much to direct the minds of our countrymen to mining and to its improvement.

In 1884-1885 the Government saw it no longer necessary to control the model mines. Accordingly all the government mines, except the Sado, Ikuno and Miike, were transferred to private hands. Of these three, the first two were afterward transferred to the Imperial Household and the last was disposed of by public tender becoming the property of Mr. Mitsui. He paid for it something over four and a half millions of *yen*.

III. The Present Epoch:

Since the transfer of government mines to the hands of the people, expenditure became less and the profits more. The consequence was a kind of mine mania. Capitalists became frantic to invest their money in mines and mine-owners for securing able engineers, so that there is now not a prefecture but what boasts of some mines within its boundary-lines.

The improvements in arts achieved during this epoch are:

1. Driving rock-drills with compressed air.
2. The use of dynamite and other high explosives was extended.
3. Wire-rope tramways were constructed.
4. The Huntington mills, Frue vanners, and Duncan concentrators used.
5. Magnetic separators were used for iron sands.
6. The Piltz and water-jacket furnaces constructed.
7. Electricity applied to the refining of crude copper and for driving machinery.
8. Boilers, engines, and turbines of new fashions adopted.
9. Mining schools established.
10. Mining societies established and mining magazines published.

The development of the mining industry during the last ten years may be judged of from the following statistics. The total value of mineral products in 1890 amounted to 15,530,000 *yens* against 7,190,000 *yens* in 1881, that is there was a total increase in 1890 of 2.16 times that in 1881:—

The	production	of gold	was	increased	2.386	times.
,,	,,	,, silver	,,	,,	2.959	,,
,,	,,	,, copper	,,	,,	3.796	,,
,,	,,	,, coal	,,	,,	2.819	,,
,,	,,	,, sulphur	,,	,,	38.420	,,
,,	,,	,, antimony	,,	,,	8.182	,,

STATISTICS OF MINERAL PRODUCTS IN EACH YEAR FROM 1881 TO 1890.

Minerals.		1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.
Gold	Ozs.	9,808	8,751	9,685	8,845	8,827	14,962	16,768	20,264	24,751	23,401
Silver	"	575,242	559,729	777,151	737,566	767,656	1,084,852	1,147,113	1,376,436	1,383,833	1,701,903
Copper	Piculs.	79,529	93,602	112,913	148,143	175,679	162,903	184,396	222,907	270,902	301,924
Copper Sulphate ...	"	925	1,039	509	731	682	1,371	453	108	1,078	452
Lead	"	4,325	3,885	4,833	1,449	1,499	3,920	6,426	6,667	10,028	12,913
Tin	"	332	296	346	466	691	1,063	1,593	1,366	880	791
Antimony	"	6,515	41,406	39,801	24,672	44,418	39,942	25,900	24,536	32,144	53,306
Arsenic	"	169	181	162	1,265	143	120	131	102	158	1,872
Manganese	"	25	2,594	2,508	2,081	2,044	6,698	5,171	13,483	15,667	43,191
Iron.....................	Tons.	15,997	12,104	14,717	11,766	6,716	13,650	15,147	18,050	20,995	22,236
Copperas	Piculs.	15,691	8,476	6,474	6,335	6,145	7,768	14,838	19,022	15,593	15,787
Coal	Tons.	925,198	929,213	1,003,421	1,139,937	1,293,678	1,374,209	1,746,296	2,007,669	2,388,614	2,608,284
Sulphur	Piculs.	11,638	56,717	115,667	71,322	82,496	107,454	179,685	380,663	316,791	442,738
Graphite...............	"	81	16	3	4	6,996	6,345	1,792	8,616	6,818	7,608
Petroleum	Gallons.	703,217	8 14,076	859,501	246,647	290,699	535,210	350,394	1,429,971	1,960,924	2,017,116

N. B.—Details of production in the year 1890 are shown in appendices.

THE PRINCIPAL IMPORTS OF MINERALS FROM FOREIGN COUNTRIES IN EACH YEAR FROM 1887 TO 1891.

Minerals.		1887.		1888.		1889.		1890.		1891.	
		Quantity.	Value in *yen*.	Quantity.	Value in *yen*.	Quantity.	Value in *yen*.	Quantity.	Value in *yen*.	Quantity.	Value in *yen*.
Lead	Picul.	22,868,53	108,835	35,913,56	201,252	31,931,50	173,487	16,057,90	85,425	20,195,52	104,028
Quick Silver.	"	686,96	54,819	817,46	73,134	1,073,88	105,416	1,066,44	102,833	1,155,01	105,660
Nickel	"	395,78	20,381	203,65	14,134	1,014,96	85,340	1,405,12	118,423	148,70	9,651
Tin............	"	866,97	31,238	1,397,90	51,502	1,677,93	58,812	2,101,31	69,281	2,122,80	71,721
Zinc	"	5,288,96	24,995	3,762,87	24,115	4,824,29	31,154	9,030,67	69,716	5,571,70	42,762
Antimony ...	"	96,89	1,011	117,88	1,810	4,25	78	—	—	—	—
Brass	"	66,12	1,087	2,496,09	89,740	121,43	4,090	109,01	2,947	1,567,81	48,238
Iron	"	108,908,68	118,369	345,706,22	397,165	163,454,54	164,148	173,823,80	185,948	203,179,14	199,209
Kerosene ...	Gallon.	21,058,865	1,871,428	28,507,767	3,519,255	36,998,843	4,587,135	42,663,580	4,950,256	40,482,160	4,535,720
Coal	Ton.	11,641	65,275	4,307	29,880	4,484	40,015	11,403	110,497	14,871	142,918

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OLD METHODS FOR ARGENTIFEROUS COPPER SMELTING.

The chief constituents of argentiferous copper ores found in Japan are in almost all cases metallic sulphides. Such ores were formerly treated exclusively by our own particular methods which are as follows :—

1. Calcination of ore.
2. Fusion of calcined ore.
3. Calcination of matt.
4. Fusion of calcined matt.
5. Leading.
6. Liquation.
7. Fusion of liquation residue.
8. Toughening of copper.
9. Cupellation.

These processes are still in operation in many primitive mines in the country.

1. **Calcination of ore** :—This operation is conducted in a pit formed in the ground, protected on all sides by rough walls of stone work. The form of this is either circular, elliptical or rectangular in its horizontal section, and the capacity of it ranges from one or two tons up to forty tons or more, as the length of it may be extended considerably without any hindrance to the process of roasting, while the breadth and height are much influenced by the nature of ores and management of the furnace. The breadth and height of a pit are commonly 1.5 to 2 m. and 1.0 to 1.5 m. respectively.

Fig. 1. represents one of the common rectangular pits. It is 2 m. long 1.6 m. wide and 1 m. high. The front wall has two openings *a*, *a*, at the lowest part. These openings, which are commonly about 0.2 m. by 0.5 m. each, serve as air doors and allow the draught to be regulated when it is necessary, by partially closing them with stones, slabs, or clay. It has no chimney, and the smoke issues from the top. These pits are arranged in numbers, in rows and in steps, side by side, on the side of a hill, and they are usually protected by rough sheds from snow and rain.

In charging a pit like the one represented in the figure, about one third ton of half dried wood is placed on the bottom of it leaving small channels for air passages in communication with the front openings *a*, *a*. Over the wood some straw or the like is laid to a thickness of about an inch, and then about 2500 pounds of ore are charged, putting larger pieces on the bottom and smaller ones on the top after which fire is applied from the openings *a*, *a*.

The roasting lasts for 15–17 days for the above charge and for a month or two for heavier charges.

The roasted ore contains 5 to 10% of sulphur and is sent for smelting.

The total expense for the roasting costs about $ 1 per ton of ore.

2. **Fusion of calcined ore**:—The calcined ore produced by the previous operation is subjected to a reducing smelting in a simple circular brasqued hearth furnace.

The construction of the hearth furnace is as follows: At first, the ground is excavated about six feet square and six feet deep. A small cross channel is then constructed of broken stone slabs across the bottom for a drain, and the remaining space is filled up with stoneslabs cemented with clay, just leaving in the middle a depression little larger than the hearth proper.

The cavity thus left is now lined with a thick layer of refractory clay; it is well dried with a charcoal fire, and afterwards it is finished with a another layer of brasque:

One or two twyers made of clay are inserted in the proper position; and then a cover is laid on the back half of the top of the hearth.

Fig. 2. represents one of the forms thus constructed. The hearth proper marked *h* is 0.45 m. in diameter, and 0.35 m. in depth, *c* is a semicircular cover made of refractory clay. *t t* are twyer nozzles to which the blast is communicated from a Japanese hand bellows called "*Fuigo*" *f* placed just behind the back wall *b*. *k* is a hood from which smoke escapes.

When the furnace is finished, a quantity of live charcoal is thrown into the hearth, and after the hearth is perfectly dry, a quantity of charcoal is again added, over which a mixture of certain quantities of roasted ore and charcoal are charged, and then the blast is applied. In about two or three hours, the charge melts, then the slag is removed and a new charge is added.

The process is repeated two or three times until from one to three tons of the ore has been melted down, when the charcoal remaining still unconsumed, together with the slag are removed until the surface of molten mattes is nearly uncovered.

The molten mass is then cooled on the surface and is stripped away as a series of thin discs by an iron hook.

During the process some black copper is produced at the bottom. This is directly subjected to desilverzation.

The consumption of charcoal is from 25 % to 40 % of ore according to the nature and fusibility of it.

The expense of this operation is for the roasted ore about $ 4 per ton.

3. **Calicination of matt**:—The discs of matt produced by the last operation are broken into small pieces 4 to 6 c. m. in size and are roasted two or three times in similar furnaces, but somewhat smaller to the furnaces previously used for ore roasting.

The mode of roasting the matt is precisely similar to the ore roasting. About ½ ton of matt is charged in a furnace with

about $\frac{1}{3}$ ton of wood as fuel. The roasting takes about 15 days and costs about as much as ore roasting.

4. **Fusion of calcined matt**:—About $\frac{2}{5}$ to $\frac{3}{5}$ of a ton of roasted matt is melted down in two or three charges in a hearth furnace exactly like that used for ore smelting. When all the charges have been melted down, the slag and dross are removed and the front half of the top of the hearth which remained uncovered, is now covered with a heavy piece of unburnt tile, supported on short pillars of the same material.

The space between the pillars, and any interstices left between the covers are luted with clay, leaving only a small opening in front, which serves to inspect the inside and also to add charcoal when necessary. This opening is loosely closed by a special tile when not in operation. An auxiliary twyer nozzle is inserted in the middle of the temporary cover and a powerful blast is directed on the surface of the molten bath. Thick fumes of sulphurous gas now issue in abundance which in three or four hours will gradually decrease and at last cease. When the reaction is completed, the temporary cover as well as the accessories are taken off and the slag is scraped out and removed.

The slag still remaining in the hearth is solidified by sprinkling water on the surface. This slag contains many globules of metallic copper and matt and is resmelted. When all the slag has been removed, next comes the regulus which after cooling is stripped off in thin discs, as in the previous smelting. Finally the molten black copper appears on the bottom of the hearth, which is also stripped off in thin discs or broken into small pieces after cooling.

The whole operation takes about ten hours with a consumption of charcoal of $\frac{1}{3}$ to $\frac{1}{4}$ % of the whole charge in weight.

The expense of this operation is about \$ $2\frac{1}{2}$ per ton of roasted matt.

5. **Leading**:—Black copper containing more than 30 ozs. of silver per ton of copper is usually subjected to this operation,

in which the copper is alloyed with about 40 % of argentiferous or non-argentiferous lead in a simple circular brasqued hearth furnace as represented in Fig.

In this figure the hearth *h* measures about 0.4 m. in diameter and 0.38 m. in depth. It is provided with only one twyer which inclines somewhat downwards. The hearth is enclosed by walls on three sides, which above form a hood so facilitate the escape and thereby prevent the diffusion of smoke and especiallly obnoxious lead fumes produced from the hearth while in operation.

At first a charcoal fire is kindled in the hearth and then about 270 lbs. of pieces and discs of black copper produced in previous operations are charged and melted down. When the copper is fused, about 67 pounds of pig lead are added, which in about an hour will completely fuse and alloy with the copper. Then the fire as well as slag and dross are scraped out from the hearth and a cold iron bar terminated by a spherical knob, whose diameter is about 0.085 m. is dipped into the molten metallic bath, on which the metal solidifies and adheres forming a thick crust. The bar is now removed and the encrusted end is immersed in cold water and the shell or crust is knocked off by a hammer. This is repeated until all the metal is removed from the hearth. Six to seven charges are operated daily in one and the same furnace with a consumption of about 20 % charcoal. The cost of producing the alloy is about $ 1½ per ton.

6. **Liquation**:—The liquation of argentiferous copper is performed in a furnace shown in Fig. 4. It has rectangular circular form covered with loam on the outside and lined with brasque in the inside. The top of the furnace is covered for the most part permanently by a heavy piece *m* of tile; leaving only a small semicircular opening in front, which is also closed by a movable tile *n*. This opening is used as a charging hole for charcoal during the operation. The open front of the furnace is also closed by a movable tile *l* which does not reach the bottom but leaves a narrow

space for the further working of the metal. An iron blast pipe *a* carries a clay twyer *b* which has a mouth *e* at the side so as to bend and to direct the blast downward. *c* is an inclined working floor formed by ramming down brasque between the side stones *d*, *d*, it continues up to the inclined bed of the furnace and terminates in a shallow circular cavity *d* which serves as a receiver of liquated lead.

About 116 pounds of the copper lead alloy produced by the previous operation are charged in the furnace in the following manner. The larger pieces are first put in on the bottom and then some charcoal is put over them, then come smaller pieces and finally ignited charcoal.

Tiles *l* and *n* are now fixed in their respective places, and the blast is turned on. As soon as the lead begins to flow and a pasty mass appears from the opening under the tile *l*, this mass is squeezed carefully with a wooden stick fastened to an iron hook, and when the mass has become too hard to yield to the stick, it is pushed back into the furnace so that it may be reheated sufficiently to render it again pasty. The process is repeated until almost all the lead is liquated out, which lasts about 2½ hours, with a consumption of about 50 pounds of charcoal. The quantity of the copper lead alloy which is operated on per day in three charges in one furnace is about 350 lbs. Cost of the operation is about $4 per ton after making the alloy.

7. **Fusion of copper residue**:—The copper residue after liquation is subjected to oxidizing smelting in a circular brasqued hearth furnace as represented in Fig. 5.

After the hearth has been well warmed, a charge of 273 pounds of the copper residue with a certain quantity of charcoal is charged into the furnace in such a manner that the surface of the metal is well exposed to the blast. In about 1½ hours the metal fuses completely, then charcoal as well as slag and dross are removed and the surface of the metal bath is blown by the blast which will cause

a copper rain. This phenomena will cease in about 10 minutes, and then the copper is removed from the furnace stripping it off with an iron as a series of thin discs.

The whole operation lasts about 2½ hours with a consumption of about 165 pounds of charcoal.

1500 pounds of the copper residue are worked in one day per hearth, producing 1470 pounds of rosette copper and 33 pounds of slag containing about 10 % copper. The expense is about $ 3 per ton of rosette produced.

8. **Toughening the copper.**—This operation is performed in a clay crucible *a* heated in a brasqued hearth furnace *b* as shown in Fig. 6.

At first the crucible is placed in the middle of the furnace, packed around with pieces of charcoal, and then a clay twyer *c* is fixed with an inclination of about 20,° and afterwards charcoal alone is charged into and piled on the crucible. Finally fire is applied and the blast is turned on, so as to heat the crucible to redness.

When the crucible has been heated to redness, the blast is stopped and some 66 pounds of rosette copper produced in the previous operation, broken into pieces, are charged intermixed and covered with charcoal, just in the same way as in previous operation and the blast is again turned on.

In about 25 minutes, the charge completely melts down, slag and dross and some of the charcoal are now removed, and the molten metallic bath is stirred well with a long hard stick of charcoal in order to toughen the metal or to reduce cuperous oxide dissolved in the molten metal, an operation which is completed in a few minutes.

As soon as the metal reaches the required toughness, the crucible is taken out of the furnace and the metal is cast in moulds under hot water whose temperature is about 80° C.

The mould is a rectangular wooden frame covered with thick cloth.

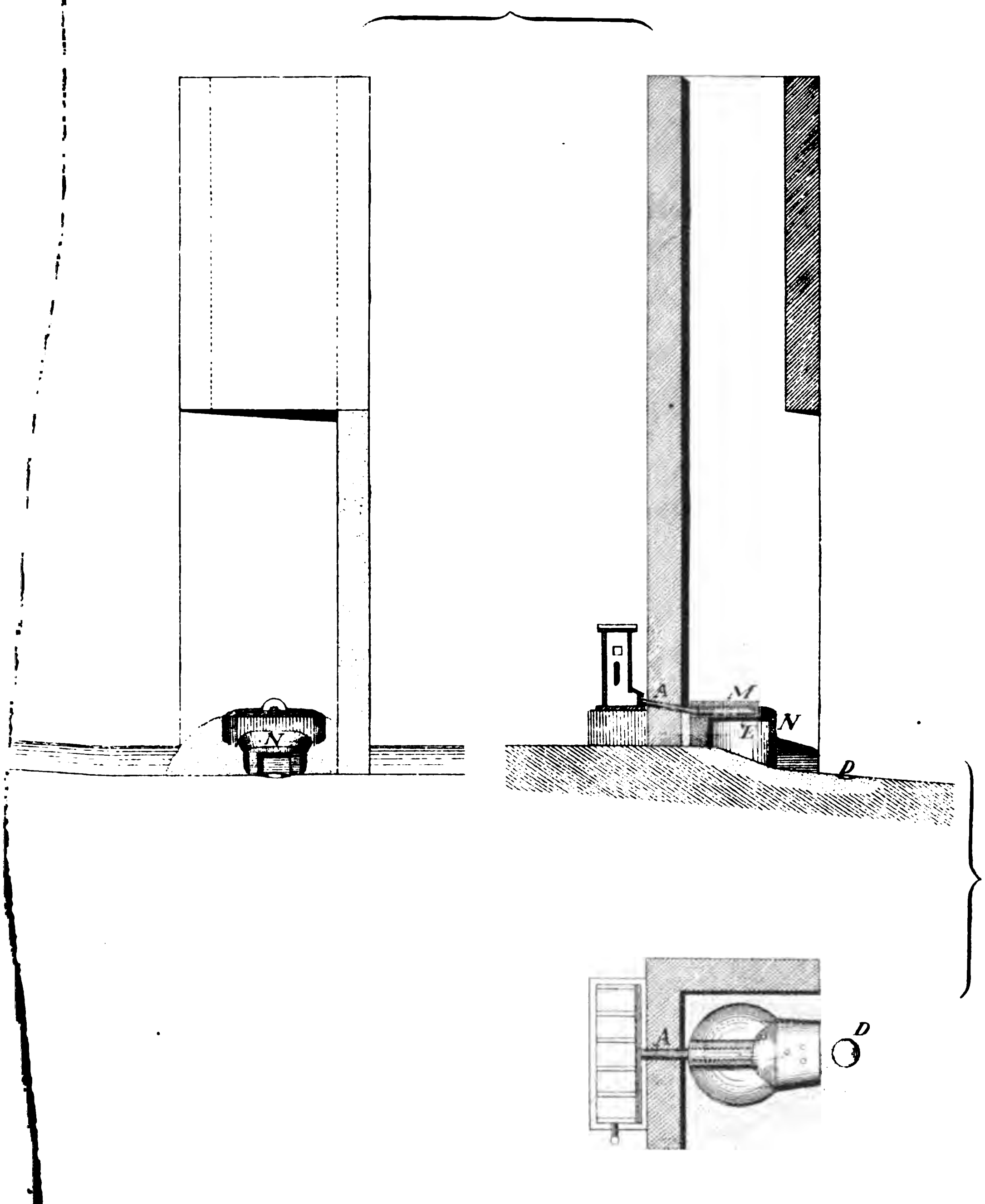
9. **Cupellation**:—Cupellation is effected in a small hearth as shown in Fig. 7. *a* is a wooden box about 1.1 m. square and 0.86 m. deep constructed in the ground; *b* is a bed or cupel formed by raining down dry wood ash, the soluble salt in which had been previously leached out; *c* is a circular cavity formed in the central part of the bed as a hearth, its form being finished with very fine and some what moist ash. *d* is a blast pipe connected with an elbow shaped clay twyer *t*, so that the blast can be directed upon the surface of the molten metal on the bed.

The charge is 88.5 pounds of argentiferous lead produced by liquation. At first the fire is kindled on the cupel and then the metal is added, and again some more charcoal is placed on the metal.

The whole charge is now enclosed with plates of square tile (0.32 m. square) and the blast is turned on. As the metal fuses the charcoal is removed to the periphery and the blast is slowly applied on the top of the molten metal. The litharge which swims on the top of the metal constantly flows to the periphery where it is absorbed by the ash.

One cupellation lasts about $2\frac{2}{3}$ hours, consuming about 20 pounds of charcoal. The button thus obtained is cooled and solidified and cleaned from dirt and is subjected to refining in crucibles, and finally cast in a mould.

FIG. 4.



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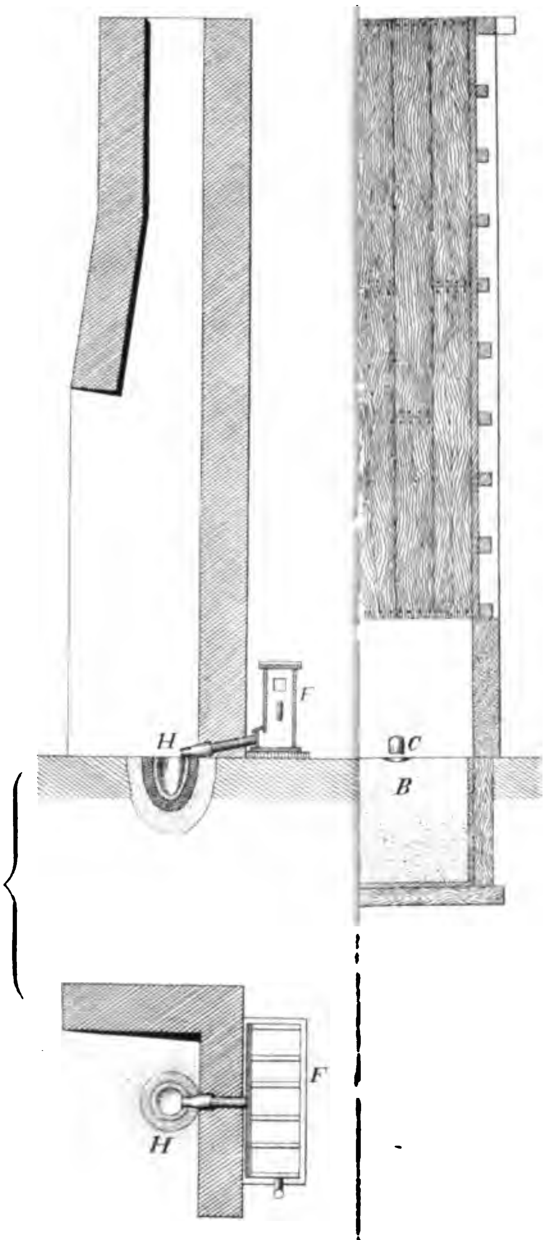
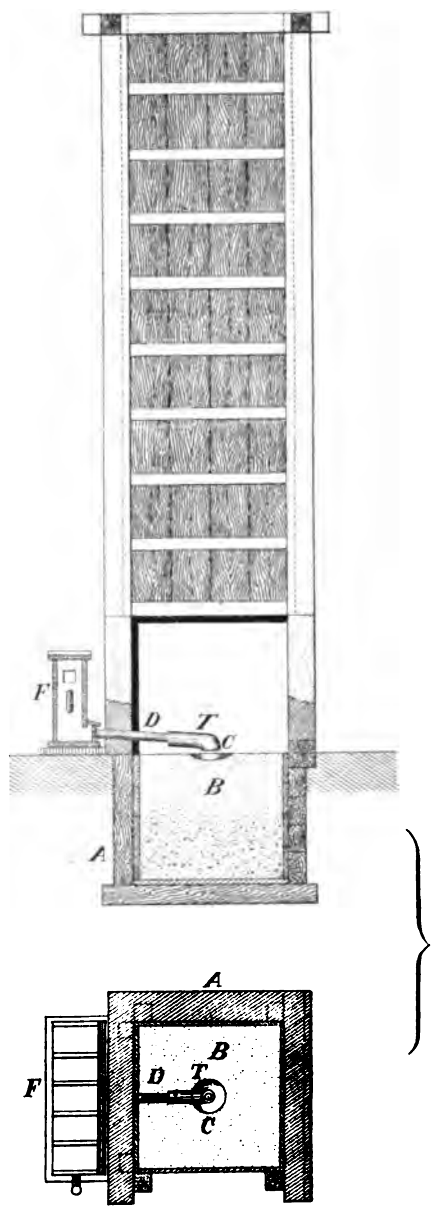


FIG. 7.



GEOLOGICAL DISTRIBUTION OF ORE DEPOSITS IN JAPAN.

The distribution of ore deposits has a relation to the geological structure of the rocks containing them, and the object here is to illustrate this fact, which up to the present has only been recognized by geologists. So far as we know, the origin of ore deposits appears to be the concentration of materials, which were either originally widely disseminated in the rocky strata, or were too deeply seated for human access. From this it follows, that ore deposits are most frequent in localities where the geological structure is favorable for such concentrations. For instance, in regions of eruptive rocks, assuming that their foundations are too weak to resist eruptions from below, fractures and fissures may be easily opened and the heat necessary for solution of substances filling up ore deposits may be supplied. Again in districts composed of metamorphosed, faulted and contorted strata, in consequence of the formation of fissures, the circulation of mineral solution and also by the mechanical development of heat, the conditions are more favorable than in the districts composed of regular strata. As the filling of ores in ore deposits is the result of slow and long processes we may infer that, the distribution of ore deposits are different in rocks of different ages,—the older the formation, the deeper is its position, the result being that pressure, heat, and solubility, are increased.

What has been above noticed, are facts, admitted by many, but do they exactly apply to Japan? Are ore deposits in this country, more widely distributed in the eruptive rocks than in the sedimentary? Do they bear any relation to the age of the country rocks? In Japan, the occurrence of oil bearing strata is confined

to the Tertiary rocks, whilst coal which is wholly unrepresented in the Carboniferous formation is chiefly scattered through formations of the Tertiary Period. Just as with petroleum and coal, we may ask whether ore deposits are restricted to formations of a certain period, or if not so, does the distribution differ according to the difference of the geological age? To discuss these important points we will first briefly refer to the geological formations and geological structures in our own country.

The sedimentary rocks represented in Japan may be chronologically classified as follows:—

Archæic Group...............	Gneiss System. Crystalline Schist System.
Palæozoic Group	Chichibu System. Kobotoke System.
Mesozoic Group	Triassic System. Jurassic System. Cretaceous System.
Caniozoic Group	Tertiary System. Quaternary System.

Archæic Group:—The Archæic rocks are the most ancient sedimentary formations met with over the earth's crust. In our country, they are chiefly developed in the districts known among our geologists as the Kitakami mountains, Kii mountains, Shikoku mountains, Hida mountains, and the plateaux of Mino and Hida. In addition to this they are also known, to a greater or less extent in the provinces of Yetchiu, Bingo, Suō, Hōki, Buzen, Hizen, Chikuzen, Chikugo, &c. In foreign countries, the Archæic Group is usually subdivided into the Laurentian and Huronian System. The latter, from a lithological and stratigraphical point of view, is known as the Gneiss System, while the former may be called the Crystalline Schist System. The chief rocks of the Gneiss System are the Kashio gneiss, biotite gneiss, Rioke gneiss, hornblende gneiss, amphibolite, granite gneiss, &c. The so-called Kashio gneiss is a variety of hornblende gneiss with a

prophyrite-like character. It is named from the locality of Kashio (Shimo-Inagōri) in the province of Shinano where it is well developed. The Rioke schist, derives its name from Rioke (Shuchigōri) in the province of Tōtomi.

The Crystalline Schist, otherwise called the Sambagawa System forms the upper portion of the Archæic Group. It is characterized by phyllitic rocks, like sericite schist, sericite gneiss, piedmontite schist, graphite sericite schist, chlorite, amphibolite, chlorite schist, epidote sericite gneiss, glaucophane schist, &c. In all of these the sericite mineral plays the most important part. Genuine mica schist is very seldom, if ever seen in the Crystalline schist of this country. Volcanic rocks, so characteristic in the geological structure of this country, also occur in the rocks of this most ancient epoch. What is gneiss? Is it not only a foliated form of granite? Does it not indirectly shew that there were granitic eruptions in the Archæic era? In fact, a close examination of the Archæic rocks, often throws more or less light on the volcanic activity of this oldest world in the geological history of Japan.

Palæozoic Group:—The rocks belonging to the Palæozoic Group are very widely developed in this country being especially well marked in the mountains of Kitakami, Abukuma, Quanto, Akaishi, Kii, Shikoku, and southern Kiushū. They therefore occur chiefly in the Outer Zone. They are also met with in the Inner Zone, as for example in Chūgoku and in the plateaux of Mino and Hida. In foreign countries, this group is usually subdivided into the Cambrian, Silurian, Devonian, Carboniferous, and Permian Systems by the characteristic fossils contained in them. In our country out of this thick development, only a few zones of crinoidal-limestone, radiolarian-slate and fusulina-limestone, can be distinguished, thus showing that only a portion of the Palæozoic rocks belong to the Carboniferous Period, Beyond this up to the present, no palæontological subdivisions have been possible. Such being the case for the sake of convenience, we now

divide our Palæozoic Group into the two systems respectively called the Chichibu and the Kobotoke. The division is a lithological one. The Kobotoke is younger than the Chichibu, the development of which is only well marked in the provinces of Quanto.

The hief rocks of the Chichibu System are pyroxenite, amphibolite, quartzite, adinole slate, clay slate, schalstein, hornstone, limestone, radiolarian slate, greywack sandstone and conglomerate. Of these, the latter is composed of pyroxenite and amphibolite, which we distinguished from other groups by the name of the "Lower Chichibu System or the Mikabu Series." The schalstein and the limestone usually occur in two different horizons of which the limestone containing Fusulina and Schwagerina, belongs with its upper schalstein, to the uppermost zone of the upper Chichibu System.

The Kobotoke System, consists of a thick mixture of clay slate and greywacke sandstone. It is well developed in the Quanto and Tsukuba mountains. Since no characteristic fossil has been hitherto discovered, and as it is found only in the above Upper Chichibu System, we can not go further than to assume it belongs either to the Upper Carboniferous or to the Permian System. If we trace the origin of such rocks as pyroxenite, amphibolite or schalstein, they naturally come from the eruptive rocks. It is not these rocks alone that throw light on the volcanic activity of the Palæozoic World, as more certain evidence of this phenomena is evident from the existence of gabbro, diorite, peridotite, diabase, diabase prophyrite, &c., These are met with as sheets and dykes. Some are changed into serpentine.

Mesozoic Group:—The Mesozoic Group is usually divided into the Triassic, Jurassic and Cretaceous System. Although they do not cover a wide area in this country, the existence of these three systems is well known by their respective fossils. The so-called Misaka and Mikura Series also belong to this group.

The Triassic System consists of alternations of sandstone and shale or clayslate. The chief districts where it appears are in Tosa, and Bitchiū. The characteristic fossil is the Pseudo-monotis.

The Jurassic System, represented in the provinces of Rikuzen, Iwaki, Yetchiū, Kaga, Musashi, Kōzuke, Yechigo, Yechizen, Hida, Mino, Kii, Awa, and Tosa is characterized by containing remains of shells and plants; sandstone, shale, or slate being its chief rocks, besides some subordinate conglomerate and limestone.

The Cretaceous System known in the provinces of Kozuke, Awa, Tosa, Izumi, Awaji, Sanuki, Higo, &c., shows no particular difference in rock-species compared to the Jurassic System. Of the many fossils contained in it, probably the most characteristic are the Ammonite and the Trigonia.

The Misaka Series is mainly composed of a thick series of tuff rocks, mostly derived from porphyrite, diabase and quartz porphyry, with which sheets and dykes of these intrusive rocks are usually associated. There are also subordinate layers of limestone, conglomerate or clay-slate. It is chiefly developed in Quanto, Shinano, Yechigo, and Aizu districts. Although this formation, as well as the Mikura Series which being mainly composed of alternations of shale and sandstone, (sometimes also with thin layers of limestone) and appearing in the provinces of Suruga, Tōtōmi, and Kii, have shown no characteristic fossils up to this day, it seems probable they may belong the Cretaceous System. Recently similar formations were discovered covering extensive regions in Tamba, Tango, Tajima, Hōki, Suwō, and other provinces of the Chūgoku. The eruptive rocks of the Mesozoic era are chiefly granite, quartz porphyry, diorite, diabase, and porphyrites: besides others which have been ultimately altered into serpentine. Often the granite passes into a variety of amphibole granite, and also sometimes into granite porphyry. The diorite may pass into quartz diorite, but such a variety as the quartz augite diorite or augite diorite is usually rare. The porphyrite is divided into hornblende porphyrite and diabase porphyrite.

Cainozoic Group:—The Cainozoic group which is subdivided into the Tertiary and Quaternary System forms the most important member of all geological groups, concerned in the development of the

present outline of Japan. It covers a wide area in the Inner Zone of North Japan. A glance at the geological map of Japan, will show how extensive a portion of her land has been added during this most recent geological era.

The Tertiary rocks are composed of tuff, shale, sandstone, and conglomerate, of which the tuff plays the most important part. The tuff varies widely in texture, some being fine-grained and compact, while other varieties are exceedingly coarse, ultimately passing into tuff conglomerate. By characteristic fossils, often well preserved in the Tertiary rocks, the existence of the Miocene and Pliocene Series can be distinguished, but with these exceptions the exact geological age of these deposits remains undetermined. The Quaternary System is subdivided into the Diluvial and Alluvial Series. The older or Diluvial Series consists of clay, loam, sand, and gravel. The earlier or Alluvial Series consists of sand, clay, mud, pebbles, etc.

Volcanic rocks, so essential in the construction of the Japanese Islands, alike with the sedimentary rocks of the Cainozoic Group, occupy an exceedingly wide area in which eruptions took place mainly in the Tertiary Period. They are chiefly andesites, liparite, and basalt. By the species of their basic constituents and by the presence or absence of quartz, the andesites are divided into augite andesite, hornblende andesite, dacite, quartz mica andesite, etc., of which the augite andesite is most common. A brief sketch of the geological formations having been given, we shall now turn to the geological structure of our land.

The general outline of lands composing the Empire of Japan, stretching from the northernmost Kurile Islands, through Hokkaidō (Yesso), Honshu, Shikoku, and Kyūshū, to the southernmost Riukiu Islands may be seen to lie in a row of different curves. Of these, the largest is the middle curve, including Hokkaidō, Honshiū, Shikoku, and Kiushiū, which is essentially made up of two important mountain axes. The northern axis trends from N. E. N. to S. W. S. and the southern one runs from S. W. S. to E. N. E. They are respectively distinguished as the Karafuto and the Sinian Mountain Systems.

These two ranges meet at the broadest, as well as the most mountainous regions of the main land, extending over Suruga, Kai, Shinano, and Yechigo nearly at the middle of Honshiū or in other words, this portion of Honshiū forms the "*Scharungsgebiet*" of North and South Japan. Here, also, one important volcanic line can be traced, the southern end of which taking its rise in the Mariana Islands passes through a series of Volcanic Islands, Bonin or Ogasawara Islands, Izu-Shichitō, Izu, Volcanoes of Hakone, Fuji, Yatsugadake, Tateshinayama, and Suwa Lake, reaching up to the volcanoes of Yake-yama in Yechigo, to which we give the name of the Fuji Volcanic Zone.

Another volcanic line similar to the Fuji Zone occurs between the "*Scharungsgebiet*" of South Japan and the Riu-kiu curve, which commencing from Torishima in Riu-kiu, crosses through Iwo-shima, Kawabe-shichitō, Takeshima, Iwoshima, Kaimondake of Satsuma, Sakurajima and Kirishima volcanoes of Osumi, Kinbuzan of Higo, Unzendake and Taradake of Hizen. This is known as the Kirishima Volcano Zone. If we glance at the geological map of Japan, it is seen that the southern and eastern regions facing the Pacific Ocean, are generally characterized by the regular developement of older and younger sedimentary rocks, being poor in eruptive rocks, while in the northern and western regions, facing the Japan Sea, differ in aspect from the former, the complicated intermixture of older and younger formations, irregular depressions, and an unusual development of effusive rocks being of common occurrence. On account of such clear distinctions existing in the geological structure, we distinguish the former from the latter, by the outer and inner zone. These zones are separated by an important line of demarkation—the Median Line—which can be clearly traced through the whole extension of North and South Japan. In South Japan commencing from the north of the Udo Peninsula in the province of Higo, it cuts the south of Aso Volcano, south of Takeda and Saganoseki in Bungo, the peninsula of Takanawa and Sanuki in Shikoku, the southern portion of Awaji, northern portion of Kii, thence bending N. N. E. at Mikawa and

following nearly the course of the Tenriugawa, meeting the Fuji Volcanic Zone in the neighborhood of Suwa Lake in Shinano. In North Japan, traversing the northern part of Quantō and the Ashio mountains, the longitudinal valleys of Abukuma, Kitakami, and Mabuchi, it leaves Honshiū at Cape Shiriyazaki and crosses the interior of Hokkaidō.

The stratigraphical and structural characters of our country, have been described the next thing is to compare the distribution of ore deposits contained in the individual formations. It must not be supposed, however, that the following discussion touches on the respective geological ages of ore deposits. When they occur as beds we know that they have been formed contemporaneously with the mother rocks, but in deposits like veins, impregnations, stock-works, massive deposits, and contact deposits, we only know that they are younger than the enclosing rocks. These facts being kept in mind, the reader is requested to look over the distribution of the principal ore deposits arranged according to the chronological succession of their mother rocks.

Archæan :—The Gneiss System belonging to the older period of the Archæan Era in geological history, is not entirely devoid of ore deposits, but it is poorer in this respect than all other formations. Perhaps, the most noted examples, are seen in the Inner Zone of North Japan. For example we have the veins of the Kamioka mine and the Higashi-Urushiyama lead mine, crossing gneiss in Hida as well as the vein of the Kamedani mine, also in the same province, occurring at the contact of gneiss and limestone, and the silver vein of Horimio in Yechizen, which also is said to pass through the rocks of this system.

Compared to the Gneiss System the Crystalline Schist is richer in the distribution of ore deposits. The copper (characterized by a compact mixture of iron pyrites and chalcopyrite) beds, of Besshi, Terano, Ose, and Chihara in Iyo, and of Higashiyama in Awa; antimony (stibnite) veins of Ichinokawa in Iyo, gold veins of Yama-

shirodani in Awa and copper veins of Yoshioka in Bitchiū are the notable examples occurring in this formation.

Palæozoic:—As examples of the principal mines, known to occur in the Chichibu System of the Palæozoic Group we may cite the copper beds of Tenwa and Tateri in Yamato, of Hibira and Makimine in Hiuga, of Itsuki and Fukada in Higo; the iron deposit of Kamaishi in Rikuchiu, of Nakakosaka in Kōtsuke, of Ohinata in Shinano, and of Iiji in Mino; the lode of the Hikami mine passing through hornstone and clayslate in Tamba, the Sankō copper mine is included in schalstein and clayslate in Wakasa, the Mandokoro lead mine crosses clayslate in Omi; the Miyakogawa, Mumegashima, and Sasayama gold mines in Kai and Suruga; the Ikuno and Nakase silver mines cut through pyroxenite in Tajima, the Toroku silver mine in Hiuga; the stream tin of the Kiura mine deposited in the limestone in Bungo; and the massive deposit of the Kanagawa gold mine.

Mesozoic:—The silver vein of Odate in Harima, passing through clay slate and sandstone; the antimony vein of Shikano in Suō, the copper vien of Udō in Izumo, crossing through the Misaka formation; the argentiferous vein of Koizumi in Bitchiu, surrounded by schalstein and porphyrite; the tin vein of Taniyama in Satsuma; the argentiferous galena vein of Sasu in Tsushima; the antimony vein of Takahama and Tsukigi, both in Higo and the Amatsutsumi mine in Hiuga; the massive copper deposit of Kokubunji and Seto in Mimasaka. Of those contained in the eruptive rocks of the Mesozoic era, may be mentioned the copper veins of Hatasa in Mino, of Obira in Bungo, and of Dōgamaru in Iwami, all in quartz porphyry; and the silver veins of Ueda in Yechigo, of Kosen and Sui in Tajima, all of which are in granite. For contact veins inserted between stratified rocks of either the Chichibu or the Mesozoic Group and eruptive rocks of the Mesozoic era, we have the copper vein of the Shiji mine in Aki occurring in contact with clayslate, porphyrite and granite; the copper vein of Obie in Bitchiu inserted between clayslate and granite;

the argentiferous vein of Nakatsugawa in Musashi, and the silver veins of Mikobata and Akenobe in the Ikuno mine of Tajima, all coming in contact with the Chichibu System and diorite and lastly the copper lode of Omodani in Yechizen, lying between Mesozoic strata and quartz porphyry.

Cainozoic :—The occurence of ore deposits reaches its climax in the Tertiary System particularly in the eruptive rocks of this period. Many important mines originated in this age. As examples of ore deposits surrounded by merely stratified rocks of the Tertiary System, we have in the province of Rikuchiu the copper vein of Osarusawa, Komaki, and Kagosawa and the massive silver deposits of Kosaka, Komaki, and Towada; in Ugo, the silver lodes of Innai and Akidōri; the copper lodes of Hisanichi, Satta, and Kawaguchi; the auriferous copper vein of Okuzu; the stock work of the Tsubaki silver mine; the impregnation of the Matsuoka silver mine; in Rikuzen, the argentiferous galena vein of Hosokura; in Iwashiro, the impregnation of the Karuizawa silver mine; in Uzen, the silver vein of Tabanematsu and the copper vein of Shachiu; in Kaga, the copper vein of Ogoya, and Yusenji, and the gold vein of Kanahira; in Harima and Idzumo, the copper vein of Uchima and Kabasaka; in the province of Tamba, the silver vein of Kuromi. The copper vein of Oppu in Mutsu; the gold vein of Sugisawa and silver vein of Hachimori in Ugo; the copper vein of Ashio in Shimotsuke; the silver vein of Handa in Iwashiro and of Kuromori in Iwaki, the gold vein of Aono and Kegurano in Izu; the silver vein of Hashima and Serigano in Satsuma and the gold vein of Yamagano in Osumi, are examples of ore deposits occurring in the eruptive rocks, especially in the andesite and liparite of the Tertiary Period.

As examples of deposits which cross both the stratified and eruptive rocks of the tertiary we have the segregation vein of Sasagatani and Ishigatani, both of which are copper mines in Iwami, which are surrounded by Palæozoic hornstone, limestone, and as the liparite; the gold vein of Kago in Satsuma, crossing through

alternations of clay slate and sandstone of an older period, and andesite; the contact vein of Tada and Sengen in Settsu, occur either in contact or cross the Chichibu system and liparite. We also have the copper veins of Hosoji and Furokura in Rikuchiu; the copper veins of Ani and Arakawa, in Ugo; the lead mine of Daira in the same province; the silver vein of Aikawa in Sado; the copper vein of Kusakura in Yechigo; the gold and silver vein of Takatama in Iwashiro; the silver vein of Ikuno, Kanegase and Asaki, in Tajima; the copper vein of Gamō in Inaba; the silver vein of Omori in Iwami, and the contact deposit of the Mizusawa and the Omaki silver mines, both in Ugo.

Ore deposits of importance are very rare in the Quaternary System. We have however the stream tin deposit of Takayama in Mino; the alluvial gold deposit of Yamashirodani in Awa and of Sajigawa in Satsuma.

We must here state, that the examples given have been selected from what have been thought to be most important, and these have been taken from an almost innumerable series. By these, however, it may be seen that Japanese ore deposits form a particular type in respect to geological distribution, just as the coal of this country being absent in the Carboniferous System occurs chiefly in the more recent Tertiary System of Hokkaidō and Kiushiu. At any rate, there is no doubt, that ore deposits are most abundant in the rocks of tertiary origin and their distribution becomes rarer as we go back to older geological periods. Considering our mines in relation to the geological structure of our country, if the copper beds of the Crystalline Schist and Chichibu System are not counted, it certainly is remarkable that so few mines are scattered in the regions of the Outer Zone. We shall see that they are very scarce in this zone which is characterized by the regularity of its geological stratigraphy, while on the contrary, they are much more abundant in the regions of the Inner Zone, where the geology is highly complicated by a confused series of earlier and later formations, as well as by a striking development of the earlier and later effusive rocks. After

all, since the distribution of our ore deposits is most frequent in tertiary regions—the age in which volcanic activity was at its maximum in the geological history of Japan—it must be necessarily inferred that the conditions most favorable for ore formation were best furnished in them.

The volcanoes and hot springs are mostly seen in the Inner Zone, or in the two Volcanic Zones of Fuji and Kirishima. When a hot spring issues to the surface, by a sudden decrease of temperature and pressure, it precipitates a portion of its soluble contents—a phenomenon which is of common occurrence. If such precipitations be metallic or a combination of metallic bases like gold, silver, copper, and lead, such an accumulation in the fissure through which a hot spring flows may after a slow and long process, form what we call an ore deposit. Not only do such phenomena appear to have actually occurred before in Japan, but they are really still observable. Look at the Yunosawa Mine of Mutsu! The argentiferous galena vein of this mine is said to become richer as it approaches the course of the subterranean sulphuretted hot spring; in the Kago and Serigano mines of Satsuma, hot springs issue in the adit level; no geologist probably denies by observing the hæmatite deposit of Matsuo in Hiuga or the silver deposit of Komaki in Rikuchiu, that such deposits are the result of anything but the action of hot springs. From observations like these we understand why the ore deposits of the Chiugoku show an intimate connexion with the liparite ; why the principal mines of Japan, are distributed chiefly in the stratified and eruptive rocks of the Tertiary Period; why many ore deposits occur in the mother rocks of older or younger eruptive origin, and why they are rarer in the regions of the Outer Zone than in the Inner Zone. After all, though by no means conclusive, most of the ore deposits in Japan may in regard to their origin, be safely admitted to bear more or less connexion to former volcanic activity.

ON THE GEOLOGICAL DISTRIBUTION OF COAL IN JAPAN.

There seems to be but little doubt that coal is the remnants of a former mass of luxuriant vegetation. These vegetable masses were either covered up by new deposits *in situ*, or drifted to another place prior to the deposition of the overlying beds. Subsequently by chemical agencies, heat, and enormous pressure of the superincumbent rock masses they were converted into coal. Deriving its origin from such a source, coal forms seams from a tenth of an inch to many yards in thickness, and these deposits may fairly be regarded as such rocks of sedimentary origin.

As coal is a form of sedimentary rock, and moreover occurs as beds or seams interstratified with such sedimentary rocks as sandstone, shale or conglomerates, we naturally search for coal in rock masses of sedimentary formations. But every sedimentary formation does not produce coal. Look, for instance, at the great coal-fields of the British Islands. They are mostly found in strata of the Carboniferous period. The coal-fields of Tonquin are also confined to the Carboniferous strata, while those of Saghalien belong to the Tertiary Period. Thus it becomes necessary, for our present purposes, to know what kinds of sedimentary rocks are developed in our country, and then to distinguish the rocks among which coal occurs from those among which it is never found. The following table shews the succession of different sedimentary formations hitherto recognized in our country, the earlier ones being placed first.

Cainozoic.	Quaternary	Alluvium.
		Diluvium.
	Tertiary	Pliocene.
		Miocene.
Mesozoic.	Cretaceous	Mikura Series (Kii, Akaishi Mountain).
		Izumi Sandstone.
		Trigonia Sandstone.
		Middle Cretaceous of Hokkaidō (Yesso).
		Misaka Series and other Mesozoic Tuffs.
	Jurassic	Torinosu Beds (Sakawa, Itsukaichi etc.).
		Jurassic Shale and Sandstone of the Southern Kitakami Mountain land.
		Cyrena and plant beds (Middle and upper Jura).
	Trias	Psendo-monotis Sandstone (Southern Kitakami Mountain land, Sakawa, Nariwa).
		Ceratites Beds (Southern Kitakami Mountain land).
Palæozoic.	Upper Chichibu Series (Carboniferous).	
	Kobotoke System.	
	Lower Chichibu Series (Pyroxenite).	
Archæan.	Crystalline Schist System (Graphite-gneiss, Granulite, Quartzite, Glaucophane-schist Sambagawa Series).	
	Gneiss System (Kaisho-gneiss, Biotite-gneiss, Rioke-schist, Hornblende-gneiss, Amphibolite, Granite-greiss).	

It will be seen from the above table that there might be many sedimentary formations likely to produce coal. Let us examine them patiently. Experience, has however shewn that in England, and most parts of the European continent and America that true coal is found most abundantly in the Carboniferous strata, and decreases *pari passu* in the succeeding earlier formations.

Looking at our country, the Carboniferous rocks are found forming the upper member of the Chichibu system in the Quantō, Ashio, Kitakami, Mino, Hida, and southern Kiushiu Mountains. They occur in thick beds of schalstein, sileceous slate, and limestone

with *Fusulina* and *Schwagerina*, the characteristic fossils of the Carboniferous period. But unhappily for us, these fossiliferous strata correspond to the lower horizon of the Carboniferous system, i.e., the Mountain-limestone, and not to the Coal-measures which is now known as the chief coal producing formation of both Europe and America. It may, further, be conjectured from the marine nature of the strata, that during the Carboniferous period, the greater part of our country was sunk beneath the deep abyss of the primeval ocean, and had not much land to support the luxuriant growth of gigantic trees and plants, which are the material for the production of fossil fuel.

The above non-coal-bearing carboniferous strata are followed by rocks of the Mesozoic era. Among them we find a number of coal seams. Let us describe them according to their ages. At the western extremity of Chiugoku, in Mine and Toyoura districts, Prov: Nagato, we find alternating beds of shale, sandstone and conglomerate, with fossil plants of the Triassic period. Coal is found in lenticular seams in the above beds and belongs to an impure variety of anthracite, easily crumbling into dust. Practically, this coal is nearly valueless; but scientifically, it is highly interesting as it is the only specimen of the earliest fragments of coal seams hitherto found in our country. In the next formation, namely the Jurassic, we notice the bituminous coal-beds of Tanimura, in Kaga, and Masakimura in Awa (Shikoku). The former occurs as a well defined seam of coal, between shale and sandstone, measuring together only one foot, while the latter is found bedded in shale about two feet in thickness in the Katsuragawa basin, and on a small scale it has been worked profitably. In the Cretaceous formation, we find coal seams in several places; the most noted among them being the anthracitic coal beds of Miyai, in Kii, and Amakusa, in Higo. The out crop of the Miyai anthracite, runs along the western side of the river-bluff, where the two rivers, the Kitayamagawa, and Totsugawa, meet. It is found as bands in clayey shale from 1 to 4 feet in thickness, and dips S.E. with a moderate inclina-

tion of from 8°–10°. It has been mined at many places along the outcrop with fair profits. The Anthracitic coal beds of Amakusa are far more extensive than those of Miyai, and are exposed along the western border of the island of Shimojima in two distinct tracts, respectively known as the northern and southern coal fields. The northern coal field extends from near Shimotsufukae southward along the coast to Tororo, a direct distance of 5 miles; and contains three seams in shales which alternate with sandstones. The two upper seams are respectively called the 8-inch and 2-foot coals, while the third and lowest seam bears the name of the 4 foot coal. All dip rather steeply towards the sea, thus giving rise to difficulties in mining. The southern coal field includes an elongated tract, extending from Ichoda southward to near the gulf of Ushibuka, a distance of more than 7 miles. The seams are much broken with upturnings and flexures; and they are inferior in quality and thickness, the thickest being only 2 feet. The coal fields of both the southern and the northern districts, especially the latter, are occasionally traversed or invaded by dykes of liparite, and the coal in close proximity with these dykes is altered in character into a kind of non-lustrous cokelike matter called "blind coal" or *Kawarake*. It will further be noticed that the anthracitic condition of coal in Amakusa may be traceable to the local effect of the volcanic overflows, as that condition becomes more conspicuous wherever the coal comes in contact with liparites. Moreover, the neighbourhood of the above coal fields is much disturbed by outbursts of these rocks. This is known as *Amakusa earth* and is employed in the manufacture of porcelain in many parts of Japan. By these intrusions common coal is changed into anthracite.

Leaving the Mesozoic coal-bearing strata, let us next turn our attention to the succeeding Cainozoic formation. Here associated with miocene plant-beds, there are large developments of coal seams. Amongst these we find most of the coal fields of Hokkaidō (Yesso), Iwaki, Hitachi, Ugo, Uzen, etc., in Central Japan or Honshiu; and Chikuzen, Buzen, Chikugo, Hizen, in Kiushiu. The greater part of

the annual production of 2,000,000 tons of coal, comes from the above mentioned coal fields, and the coal contained in these fields available at depths not exceeding 500 feet below sea level is estimated at more than 600,000,000 tons. In fact, our older Tertiary formation (Miocene) in point of producing coal, may fairly be likened to the Coal-measures of the British Islands. Commencing with Hokkaidō,—the northernmost part of the Japanese Islands, the following are short descriptions of some of the above mentioned coal fields.

Although the coal beds of Hokkaidō are distributed in many provinces, such as, Shiribeshi, Kushiro, Teshio, Hidaka, etc., yet none of them surpass in size and quality those of Ishikari. Among the latter may be mentioned the Sorachi, Otaushinai, Ikushunbets, Poronai, and Yūbari, coal fields; and it is in coal fields where the company called the Tankōtetsudō-gwaisha (Coal and Railroad Company) is working or opening with success and vigour. The Ishikari coal fields, taken as a whole, run from north to south, the seams dipping east or west, forming many synclinal troughs or basins. Their inclinations which are steep towards the north become moderate as we go southward. The coal beds are dislocated by numerous faults, and these faults often bring the same coal seams again to the surface.

The coal fields of Central Japan or Honshiu produce coals of inferior quality, and belong mostly to brown coal or lignite. The coal field of Hitachi and Iwaki is situated, along the eastern border of the Abukuma mountain-land, facing the Pacific Ocean, It extends from Nogami southward to Tomobe; forming an elongated tract, with its longer diameter of more than 50 miles. Though the coal crops out to the surface over such a large area, seams of workable thickness are only found at its central part, where the collieries of Onoda and Shiramizu lie. The strike of the coal beds exposed at Onoda bears N. 30° E., and they dip with a gentle inclination of 5° towards S.E. The workable thickness of coal measures 5 feet. The coal bands contained in the

Shiranuzu colliery are two in number, viz., the 3-foot and 6-foot coals. Both dip gently towards S.E., with a strike N. 60° E.; and the lowest 6-foot coal yields lignite of fair quality. On turning our gaze westwards from the Pacific side to the coast of the Japan Sea, we observe many patches of small coal fields. The following are examples:—

The seven foot coal of Kayakusa (Ugo), with steep faults and often steep inclinations; the little coal basin of Abrado (Uzen) with 3 beds; the faulted 10 foot coal of Akadani (Yechigo), &c., &c.

All produce brown coals of rather inferior quality, and consequently, they are of little commercial importance. Another set of coal beds worthy of mention is that of the coal field of Funaki, situated at the southern part of Nagato, near the sea coast. The coal is found in gently undulating beds, and there are seams known respectively as Futae, Yoe, Nakabori, Sokobori, Chiugū, Santoku, of which the Nakabori (3½ feet) and Chiugū (2½ feet) are workable.

In Southern Japan, or Kiushiu, we find the most productive coal fields. They are distributed in the older Tertiary formation developed in the northern provinces of Kiushiu; viz., Chikuzen, Buzen, Chikugo, and Hizen. The most important coal fields of Chikuzen are found in basins along the Kamagawa, and at the south and north of the district Kasuya, not far distant from the sea-port of Hakata. The coal beds along the Kamagawa and its tributaries are divided into two or more elongated basins by longitudinal mountain masses of older rocks which exist between them. The general strike of these beds run from N. N. W. to S. S. E., and they dip eastwards at a moderate angle; but wherever they come in proximity with the eastern margin of the harder mountain masses, they dip suddenly westward forming acute synclinals, and the coal beds near these synclinals are subjected to numerous faults and irregularities; and their value is deteriorated. These are more than 10 seams, but those deemed workable with fair profits are the 3-foot and 5-foot coals. Both yield bituminous coals of good quality. A coal closely resembling artificial coke has been

worked for lime burning etc., and is locally known as *Senseki* (Spritting coal). This is nothing more than the product of a common coal bed in contact with volcanic rocks (Andesite) which traverse the district either in dykes or sheets in various forms. The little coal basin situated at the northern part of the Kasuya district is rather interesting as it dips on all sides towards the centre, and is nearly skirted by its base rock, a member of the pyroxenite series. It contains two workable seams of 3-feet and 5-feet respectively. Another coal basin, located at the southern part of the Kasuya district, also forms an irregular elliptical trough upon the granite and pyroxenite rocks; and exhibits numerous coal seams of from 1 to 3 feet in thickness. Some of them are worked and produce coal of excellent bituminous quality.

The coal-producing tracts belonging to the province of Buzen are found near the town Kokura, and also along the Chiugenjigawa, one of the tributaries of the Kamagawa. The former contains, (though inferior in quality), a workable seam of 5 feet in small basins while the latter is the continuation of that of Chikuzen developed along the Kamagawa. Here we find two workable seams of 8-feet and 4-feet thickness which are of excellent bituminous quality. The same coal seams are here found exposed on the surface in three parallel areas by step faults. The above 8-feet coal is often interfered with by sheets or dykes of andesite, thus changing locally its character into a kind of natural coke. In Chikugo, we have only one coal producing tract. This is the site of the celebrated Mieke Colliery. The outcrop of the coal seams runs from W. N. W. to E. S. E. and they dip gently towards the south. At present, the 6-foot and 8-foot coals are worked, and there is a daily output of not less than 1000 tons. In the older Tertiary formation developed in Hizen, and its adjoining islands, are found coal beds of various extents and importance. Among them, we refer to the coal fields of Karatsu, with workable 5 foot coal, and also those of Takubaru, Fukumo, Kita-matsuru, Higashi-sonoki, etc., with numerous coal seams from a few inches to more than 2 feet in thickness. The coal beds

of Matsushima produce 4 to 8-foot coals and are those of Takashima, the upper 8-foot, the Goma 5-foot, the Bando 5-foot, 3-foot and 18-foot coals. The latter 18-foot coal is the thickest coal seam found in Kiushiu. The above coal bed extends southwards to the Islands of Hashima and Nakanoshima, and they are worked, together with those of Takashima, by the Mitsubishi Company.

The earlier Tertiary formation or Pliocene has also coals, though less in extent and quantity. They belong to an inferior variety of brown coal or lignite, and are locally known as *Iwaki* (Rock tree), in consequence of completely shewing the structure of the original wood. The lignite-beds of this kind are found mostly in the central part of Japan, in Owari, Omi, and Iga; along the coasts of the islands of Awaji, and Shodoshima; and also in Yada (Izumo Prov.), Noritsuke (Kōzuke Prov.) etc, Their inclinations are generally moderate, and their thickness seldom reaches 5 foot. They have been worked and used as fuel.

The coal of the succeeding quaternary period is represented only by spongy felted masses of half carbonized vegetable matter known as peat or turf. It is distributed mostly through the northern part of Japan, especially in Ugo, where it has been profitably used as fuel or manure.

In conclusion, we may say that the earliest fragments of our coal seams are formed in Triassic times attaining their greatest development in the older Tertiary, while the coal beds of England and most of the European continent and America culminated in the Carboniferous formation.

STATISTICS OF STEAM AND WATER POWERS USED IN THE MINING INDUSTRY OF JAPAN.

Prefecture.	Steam Boilers.		Water Wheels.		Total.	
	Number.	Horse Power.	Number.	Horse Power.	Number.	Horse Power.
Tokyo	1	10,0	—	—	1	10,0
Osaka	1	8,0	—	—	1	8,0
Kanagawa	—	—	1	2,0	1	2,0
Hiogo	3	48,0	3	20,0	6	68,0
Nagasaki	48	1,491,0	—	—	48	1,491,0
Niigata	20	617,0	3	14,0	23	631,0
Gunma	1	12,0	—	—	1	12,0
Tochigi	22	688,0	12	1,037,0	34	1,725,0
Nara	—	—	—	—	—	—
Miye	—	—	1	,5	1	,5
Shidzuoka	1	15,0	—	—	1	15,0
Yamanashi	—	—	1	33,0	1	33,0
Gifu	1	50,0	17	248,0	18	298,0
Miyagi	5	165,0	7	27,0	12	192,0
Fukushima	8	280,0	9	64,0	17	344,0
Iwate	2	20,0	25	199,5	27	219,5
Aomori	1	6,5	—	—	1	6,5
Yamagata	1	5,0	4	10,0	5	15,0
Akita	38	768,0	30	259,0	68	1,027,0
Fukui	—	—	3	28,0	3	28,0
Ishikawa	4	75,0	15	150,0	19	225,0
Tottori	1	10,0	4	22,0	5	32,0
Shimane	4	96,0	5	23,7	9	119,7
Okayama	1	8,0	—	—	1	8,0
Yamaguchi	22	482,0	—	—	22	482,0
Yehime	13	104,0	5	64,0	18	168,0
Fukuoka	198	5,813,0	3	44,0	201	5,857,0
Saga	52	667,0	—	—	53	667,0
Kumamoto	5	80,0	—	—	5	80,0
Miyasaki	—	—	—	—	—	—
Kagoshima	5	41,0	470	317,2	475	358,2
Total	458	11,559,5	618	2,562,9	1,077	14,122,4

LIST OF REPORTS.

The reports on the following mines though still imperfect will show some features of the present working.

1. Sado Mine (Gold and Silver).
2. Ikuno Mine „ „ „
3. Innai Mine (Silver).
4. Handa Mine „
5. Karuisawa Mine (Silver).
6. Kosaka Mine „
7. Towada Mine „
8. Omori Mine „
9. Omaki Mine „
10. Tsubaki Mine „
11. Kamioka Mine (Copper and Silver).
12. Mozumi Mine „ „ „
13. Hadasa Mine „ „ „
14. Ani Mine (Copper) and Mukoyama (Silver).
15. Ashio Mine (Copper).
16. Besshi Mine „
17. Arakawa Mine „
18. Kusakura Mine (Copper).
19. Omodani Mine „
20. Ogoya Mine „
21. Yoshioka Mine „
22. Osarusawa Mine (Copper).
23. Komaki Mine „
24. Kokubunji Mine „
25. Ose Mine „
26. Iwaya Mine „
27. Ichinokawa Mine (Antimony).
28. Neu Mine (Iron Sand).
29. Yoshida Mine (Iron Sand).
30. Miike Mine (Colliery).
31. Takashima Mine (Colliery).
32. Nakanoshima Mine „
33. Hashima Mine „
34. Ishikari Coal-fields: Poronai Colliery. Ikushunbetsu Colliery. Sorachi „ Yubari „
35. Atosanobori Mine (Sulphur).
36. Iwaonobori Mine „
37. Ichibishinai Mine „
38. Osorezan Mine „
39. Arayu Mine „
40. Amase Petroleum well.

SADO GOLD AND SILVER MINE.

Situation :—Gold veins are found here and there throughout the whole island of Sado. Many of them were tried in bygone times, but only excepting those of the two claims, Aikawa and Tsurushi have been abandoned. The former, the richer of the two, is one that has but few parallels in the whole country. Going eastward the outcrops of veins are seen along a streamlet less than one mile from the coast of Aikawa.

The Tsurushi claim is situated about one half mile eastward from Sawane and some two miles south of Aikawa, opposite to the other mine. It remained idle until 1890 when dead work on an extensive scale was commenced upon it. It is hoped that mining will become possible at no distant date.

General History :—The first notice of the presence of gold in the island of Sado was the discovery of gold dust at Nishimikawa, Kamo-gori. The date is not exactly known, but it is certain that it was not later than nine hundred years ago, as may be inferred from the following statement in a book styled "Uji Shūi Monogatari" written by Dainagon Takakuni at about that time :—

"An iron miner of Noto knowing of the presence of gold in Sado informed his liege lord of the fact. The latter ordered him to bring him some of the precious metal. Thereupon the miner went over in a small junk and did as he had been ordered." The gold he brought back is believed to have been gold dust from Nishimikawa.

A book, the "Sado Fudoki," states :—"In 1593 peasants of Nishimikawa sold their leeks to a sailor from the mainland. While washing the vegetables, the sailor observed gold dust among them.

He went to the garden where the leeks had grown and took a quantity of the soil to his ship without telling the good people. Afterwards the peasants found it out and did not allow the sailor to land again. Later, the gold they obtained was sent to Taikō as tribute." That Taikō received this tribute is stated in his letter to Uyesugi Kagekatsu.

The Tsurushi mine, also called Hyakumai Mine (i.e. one hundred plate mine), was discovered and located as follows :—

In 1593 (1542 according to Sado Annals), the crew of a merchantman from Echigo, while sailing off the coast of Sawane, observed, far up on the mountains, a strange bright light. This they thought to be gold and it proved so upon examination. The sailors and the natives of the place received permission from the governor, Homma-Settsu-no-Kami to work the ores they found, by offering him a monthly tribute of one hundred silver plates from January of the following year.

The Aikawa mine was found thus :—Two miners, Miura and Watanabe, of the Tsurushi mine thought there must be gold veins in the mountains lying to the north. After a painful search in 1601 they discovered what is now the Aikawa mine. For about the first quarter of the 17th century the quantities of gold and silver it produced were enormous. What turns of prosperity it had since that time until the the Restoration is precisely recorded in Count Katsu Awa's *Suijin Roku.*

Ore Deposits :—The Aikawa mine has three great fissure veins. Their strike is from east to west. Of these the southernmost is called the Aoban vein, the middle the Otate vein, and the northern-most the Torigoe vein. The veinstuff is quartz. The first two are rich in gold and in addition contain silver. The last is poor in gold and contains silver and copper. The first is nearly 100 feet wide in its broadest part, but little over 1 foot in the narrowest. The length hitherto ascertained is :—the Aoban and Torigoe veins each some 1½ miles, and the Otate about ½ mile.

The veins of the Tsurushi mine are the same as those of the Aikawa mine. They are four in number and run quite apart from one another, striking east to west or north to south. Their breadth is nowhere more than several feet. The metals they contain are silver, gold, and copper,—the proportions in which they are present varying with each vein. They are far inferior to those of the Aikawa mine in breadth as well as the qualities of the ores.

Geological Formation :—The Tsurushi mine is geologically similar to the Aikawa.

The minerals contained in the veins are native gold, argentite, stephanite, pyrargyrite, copper pyrites, bornite, galena, zinc-blende, marcacite, calcite, quartz, etc.

The rocks belong to the Tertiary group and are of aqueous origin. The tuffs which are green, gray, or purple in color and coarsely broken in many places, and shales which are of gray, black, green, or such colors, both ranged in strata, are the principal members of the series. Augite andesite is also found in many places.

Grade of Ores :—

Ores.	Gold.	Silver.	Copper.
Gold and Silver Ore.........	0,00124 %	0,0181 %	———
Copper Ore	0,00030 „	0,0216 „	2,8500 %

Shafts and Levels :—

1. Shafts.

The Great Shaft .... 900 feet deep.
„ Takatō „ .... 850 „ „
„ Torigoe „ .... 350 „ „
„ Ogiri „ .... 350 „ „
„ Hyakumai Shaft .... 340 „ „

2. Levels.

Total length.. 42,496 feet.

Site of the Mill:—The mill is situated ¼ miles from the coast in one corner of the town of Aikawa. Its different departments are on both banks of a streamlet, called the Nigorikawa. The ores are first brought to a place some height above the mill and thence taken downward through various apparatus arranged in steps.

Metallurgy Prior to the Restoration:—

1. Crushing and Pulverization of Ores.—A stone enclosure 3 feet square and 3 feet high was first made. In the centre of it a hole was dug and in it was placed a hard stone upon which to break and pulverize ores by means of iron hammers, each weighing some 30 pounds. The pulverized ores, if of first rate quality, were sifted through horse-hair sieves having 40 meshes to a square inch, but if of second or third rate, through bamboo sieves.

2. Concentration.—The pulverized ore was reeved in dolly tubs and that portion which floated was transferred into launders, while the other portion which sunk was further concentrated in vanning troughs. The tailings from the troughs were ground in stone mortars and treated as above described once or twice with the second and the third rate ore and several times with the first rate. The slime was made to flow in launders down a concentrator named *neko*, in a stream of water. The *neko*, which was a frame over which a coarse cloth was stretched, was about 10 feet long and set obliquely, the inclination being 7 inches to the foot. That portion of the slime which remained on the cloth, was again treated in dolly tubs, vanning troughs, etc. as before described.

3. Roasting of the Concentrated Ores.—The concentrated ores, except the auriferous, were made into balls as large as geese's eggs with clay and water. These balls were heaped on charcoal fires in hearths made of earth. The ores had thereby their sulphur removed and their minerals oxidized.

4. Smelting of Concentrated Ores.—The concentrated ores mixed with suitable proportions of lead were melted in flat hearths, using charcoal for fuel and wooden bellows for blowers. The products of this process were auriferous lead and matte.

5. Roasting of the Matte.—The matte was heaped 1½ to 2 feet high on dried brushwood in a round hearth of about 3 feet in internal diameter and with one or two air-holes near the bottom. Upon the matte pulverized ore or matte was thrown in and the whole was bored through to let the smoke out. The fuel was ignited at the air-hole. The whole process took five or six days for its completion. The well roasted ore was selected and sent to blast furnaces.

6. Smelting of the Roasted Matte.—This was effected in a manner similar to smelting the concentrated ores and the products obtained were precious lead and copper alloy.

7. Liquation.—This process was for removing lead from the alloy and obtaining precious lead and liquated copper. The latter was again smelted with a suitable quantity of lead and made into alloy, which was once more worked for precious lead and twice-liquated copper.

8. Preparation of Copper.—The liquated copper was obtained from the lead and slag by heating it.

9. Cupellation.—The precious lead was heated with strong blasts from bellows. The lead being oxidized and absorbed by the ashes, there remained only gold and silver bullion. With the precious lead from auriferous concentrates, gold bullion containing silver was produced, and with that from the first class silver ore and the second and third class ores, silver bullion containing gold was the result.

10. Desilverization.—The bullion made from the first class silver ore and the second and third class ores was fused in a flat hearth and lead and sulphur added to convert the silver into sulphide. The silver matte thus produced was sprinkled with water and pared off leaving gold on the hearth floor.

The silver matte was again and again treated with lead, until all traces of gold were removed. It was then heated violently, had its

sulphur removed, received lead, and was made into argentiferous lead, which was cupelled and manufactured into bullion.

The gold bullion containing silver was cupelled with lead and the cupelled product was pulverized, mixed with common salt, and made into cones of proper size. These cones being strongly heated, a portion of the silver was converted into chloride and thus separated. The bullion purified in this manner was further treated till it came up to the standard of the *Hoji Koban*.

Metallugy Introduced after the Restoration:—

The improvement of the dressing and metallurgical operations was commenced in 1872 and though still in progress, what has been already accomplished is not inconsiderable. For example, the appliances for dressing, battery amalgamation, smelting, pan amalgamation, and barrel amalgamation have been completed and are at present actually in use. The precipitation machinery is not yet fully completed. The whole is roughly as follows:

1. Dressing.—This is of three categories, *i.e.* dressing of gold and silver ores, that of auro-argentiferous copper ore, and that of amalgamation pulp.

a. The dressing of gold and silver ores is done by means of 1 rock-breaker, 5 Huntington mills (each 3.5 feet diameter), and 10 Frue vanners. The poorest ores are treated in this process. Amalgamation is resorted to along with this process.

b. The dressing of auro-argentiferous copper ore is effected by means of 1 rock-breaker, 1 Chrome roll, 3 conical trommels, 1 classifier, 3 double-sieved coarse jiggers, 3 double-sieved fine jiggers, 3 Huntington mills, 3 pointed boxes, and 6 Frue vanners. The crushed ores from the Chrome rolls fall directly upon the trommels and properly classified go to the jiggers. The tailings are further treated in Frue vanners.

c. The dressing of the amalgamation pulp is done by means of

2 centrifugal pumps, 3 pointed boxes, 6 Duncan concentrators and 4 continuous conical buddles. The pulp from the separators is thrown into the pointed boxes by means of the centrifugal pumps, wherein it is separated into sands and slimes. The former then go to the Duncan concentrators and the latter to buddles to be further concentrated. The concentrated ores all go to be smelted.

2. Battery Amalgamation.—The works for this process have 1 rock-breaker, 30 California stamps (each weighing 850 lbs.), 6 amalgamated copper plates, and 6 Duncan concentrators. The ores here treated are poor ones, which have not been hitherto worked as unprofitable. The concentrated ores go to the pan amalgamation works.

3. Smelting.—The works have two water-jacket furnaces of which one 36 inches in internal diameter is used for ore-smelting and the other 27 inches in internal diameter, for matte-smelting. In connection with these furnaces there are Baker's blowers, Vortschaufelung's calciners, Freiberg kilns, etc. The chief ores worked are concentrated ores and cupriferous iron sulphide, the former of which being very fine are roasted and oxidized in the calciners to remove sulphur and other admixtures while the latter is calcined in the kilns. These ores are then fused in the ore-smelting furnace together with dolomite and basic slag with coke as fuel. The coarse-metal thus obtained is powdered, mixed with concentrates and heated in calciners. When partly fused it is taken out and put into the matte-smelting furnace together with slag. The products are copper matte and black copper. The former is worked similarly to the coarse-metal while the latter, having been remelted in a furnace of special make, its admixtures has removed and is afterwards moulded into what are called rectangular auro-argentiferous copper blocks.

4. Pan Amalgamation.—The works have 1 rock-breaker, 25 California stamps (each weighing 650 lbs.), 14 Mackcorn's amalgamation pans and 7 separators. The chief ores worked are the first and

second rate gold and silver ores. The chemicals used are copper sulphate and common salt, which are employed in the usual manner. The gold and silver amalgam obtained is sent to the refining works and there retorted. It is fused in a graphite crucible and moulded into mixed bullion.

The slag from the first class ore is kept in pits and afterward worked again by the pan amalgamation process. That from the second class ore is allowed to flow to the pulp concentration works.

3. Barrel Amalgamation.—This is for working the slime from the pan amalgamation process and also slag from the ores worked before the Restoration. It is a special process to work uncalcined ores. It employs 2 large barrels each of 2 tons capacity and 2 separators. The amalgam and tailings produced are treated as in the pan process.

Improvements in Metallurgy :—In 1871 improvements were made in the metallurgical works. In 1874 these improvements gave pretty satisfactory results. The most important introduction was the adoption of the pan amalgamation process.

As to dressing in 1875 the Rittenger and Saruppury launders were adopted for dressing copper ores and as regards smelting a Stolbery furnace of brick was made which was ready for work in 1876.

The pan amalgamation process in 1883 was almost perfect. Still it was necessary to rework the slime by this process. This trouble led to the adoption of the barrel system. The tailings from the latter process had still some copper and lead, which was too much to be lost. This loss ceased with the establishment of the concentration works in 1890.

The dressing works set up in 1875, efficient as they were, were not quite equal to the work of the smelting furnaces. So in 1889 they were improved as alreary described, thereby increasing the percentage of extraction and decreasing the expenditure.

The smelting works started in 1875 at first encountered considerable difficulties. The ores were highly silicious, the concentrates

alone containing 30 to 50 % of silica. There was no suitable fluxing material, the old slags picked up here and there about the mine and dolomite being the only material of the kind. No fuel but wood charcoal could be easily got. Time and experience, together with a gradual increase in the production of the slag from the matte-smelting furnace and what proved another factor, the purchase of coke at reasonable rates assisted matters. Eleven painful years passed with but occasional glimpses of hope, when iron sulphide made its way into the work and annihilated all the past difficulties. The furnaces themselves were greatly improved while Frendenberg dust chambers made it possible to save every particle of metallic dust.

Since 1877 no foreign engineers have been employed.

Supply of Fuel:—For steam-boilers and roasting furnaces coal, for in smelting furnaces coke is used. The coal annually consumed amounts to several tens of thousands of tons, of which several thousands are taken from the Aburado coal mine in Nishitagawa County, Yamagata Prefecture, which is attached to this mine, and the rest is bought either from Hokkaido or Kiūshiū according to the condition of the market. Charcoal, which is required in no great quantities, is bought from villages within 12—15 miles around the mine. But it is sometimes purchased from Noto. Wood, which is used only in small quantities, is easily got from the surrounding forests.

Production Statistics:—The production of the mine for nine months from April to December inclusive of 1891 is as follows:

Gold	5,715.37	oz.
Silver	95,124.97	„
Copper	31,199.80	lbs.
Lead	7,998.30	„
Blue vitriol	587,000.00	„

Percentages of Extraction :—

	Gold.	Silver.	Copper.
Gold and Silver ore dressing	93	55	—
Auro-argentiferous copper ore dressing	95	70	85
Smelting	98	94	94
Pan amalgamation	90	70	—
Barrel amalgamation	70	70	—

Steam Power :—

For mining .... 185 horse-power.
„ dressing.................... 375 „

560 horse-power.

Transportation :—The principal adit levels have I—rails manufactured at the works of T. Krupp, Germany. Upon the rails wooden wagons, each 1,000 pounds capacity, are drawn either by horses or men. Winding machines horse whims and other contrivances for vertical transportation are placed at important points in the pits.

Out of the pits the chief roads have also Krupp rails and horses are used for drawing wagons. In one place a stream is led into a wooden tube and ores are transported in the current of water. Where rails are not laid, horses or men transport ores or other things on their shoulders. As there is no wide space about the mill, a Bleichert's wire tramway was constructed in 1887 for carrying the worthless tailings, rubbish stone, coal ashes, etc. away to the sea-coast.

Distances to Markets :—

To Niigata ; 15 miles by land and 32 naut. miles by water.

To Hakodate ; 190 miles by land and 109 naut. miles by water.

IKUNO GOLD AND SILVER MINE.

Situation :—The Ikuno Gold and Silver Mine is at the town of Ikuno-machi in Asago-gori, Tajima Province, Hiôgo Prefecture. It is on the river Asago-kawa about 26 miles north of Himeji and 334 metres in height above the sea level.

General History :—This mine was discovered more than one thousand and eight years ago, though it was not until 1542 that it became of any importance. It was most productive between 1688 and 1710, yielding over 1,023.781 *kwamme* of silver per year and the least so between 1844 and 1847, the annual produce of silver then being about 166 *kwamme.*

Geological Formation and Ore Deposits :—Since mining has been carried on at Ikuno the ores produced have come from three principal mines or ore-deposits which are as follows :—

1st : The *Ikuno proper* comprising the 'Tasei' gold and silver lode and the 'Okuhi' silver and copper lode with many secondary veins.

2nd : The *Kanagase* consisting of the 'Kanagase' copper and silver lode and of numerous complimentary lodes some of which were richer than the main vein.

3rd : The *Kasei* silver lode.

At Ikuno proper where the metallurgical works are established and the Office erected, and the Kanagase group situated two to three miles east of the former, have their mineral veins in similar country rocks and the ore deposits belong to the same geological age.

The porphyritic liparite and granular andesite (augite-propylite) arranged in alternating sheets as for example, as observed in the adit

No. 3 of Tasei, with intervening tuffs containing burnt wood, constitute the mother rocks of these two ore-deposits.

Besides the above mentioned volcanic rocks, basalt with and without olivine and of distinctly crystalline texture, occurs in Kanagase mostly. This appears to bear an essential relation to the lodes as it is generally found as dykes and gangues of different dimensions and in different situations cutting through the lodes as well as the tuffs covering the superficial part of the mountains. Here and there the lodes are dislocated, rendering the mining works complex and difficult.

The metalliferous quartz veins pass through the stratified tuffs derived from the liparite and andesite, but in turn they are broken through by the basalt. The basalt is therefore the youngest of all rocks. The ores from these veins are auriferous pyrites, argentite, pyrargyrite, tetrahedrite, argentiferous galena, bornite, chalcopyrite, iron pyrites, blende, native silver, native bismuth and probably stephanite, and some carbonates from old works.

The third district Mikobata is situated northwesterly from Ikuno about ten miles distant.

A big quartz vein called 'Kaseibi' worked at different stations which are equally productive over a length of two miles. The widest part of the lode is said to be forty feet. The country rock is a schistose diorite, like amphibolite, but of decidedly eruptive origin, generally poor in quartz. The same liparite, as occurs at Ikuno, occupies the higher part of the mountain where it seems to have protruded and flown down along the slope. This acidic rock as well as the basic green rock, (propylitic), repeatedly cut through the main lode and in certain situations considerable dislocation is the result. The thickest part of the liparite dyke surpasses that of the lode while the propylite does not measure more than six feet.

The ores are argentite, ruby silver, copper pyrites, iron pyrites, galena, and zinc blende, in quartz and calcite vein-stuff as in Ikuno.

Quality of Ores :—The ores lose about 37 % of their weight in the process of picking. The picked ores contain gold, silver, copper and lead in the following proportions :—

Gold and silver ore..............	Gold.........	0.00047 %
	Silver	0.04263 ,,
Silver and copper ore............	Silver	0.02410 ,,
	Copper ...	0.45351 ,,
Lead ore	Silver	0.12000 ,,
	Lead	30.00000 ,,
Iron pyrites	Silver	0.04210 ,,

Shafts and Levels :—This mine has two shafts, whose total depth is 765 feet. The levels are 36.270 feet long in all.

Cost of Mining :—The cost of mining is 2.859 *yen* per 1,000 kilogrammes of dressed ores.

Site of the Mill :—The mill is situated at Ikunomachi, Asago-gori, Tajima Province, Hiôgo Prefecture.

Metallurgy Practiced before the Restoration :—The Tasei Mayebi vein, which was very productive in bygone days, has produced an ore which contains both gold and silver. Before the Restoration assaying was, however, almost unknown, and therefore this ore was considered as merely an argentiferous ore. Moreover the only metallurgical process known was that of smelting. Now this ore containing much silica was very refratctory, and so it was mixed with the cupriferous ore before subjecting it to smelting. The affinity between gold and copper being very strong, the common process of liquation then known could not separate the one from the other. Without knowing it the gold was left in copper and sent to market as nothing more precious than the latter metal.

The process of treating this kind of ore was as follows :—

First, the ore was broken into pieces about the size of peas and the rubbish removed. That portion of it which was in the form of

powder was treated with bamboo mats or bowls. Roasting was not resorted to. The three kinds of ore, the silver ore, copper ore, and iron pyrites, were mixed in suitable proportions and to this mixture a little quantity of slag was added.

The above mixture, together with charcoal, was thrown into a ground hearth 1.5 feet in diameter and 8½ inches deep, the floor and walls coated with a mixture of clay and pulverized charcoal. The air was forced in from the bellows set at the back of the hearth. As the mixture fused, the slag was removed and the copper matte of an inferior grade forming in the hearth was strongly heated by forcing in violent blasts from the bellows placed in front of the hearth. The iron matte appearing on the surface, as the sulphur in the copper matte escaped in the form of sulphurous oxide, was immediately removed, while to the copper, now completely reduced certain quantities of the lead ore and lithage were added. Now to prepare what was termed copper alloy out of this mixture, it was briskly stirred and violently heated. The copper alloy prepared was fused in a liquating furnace with a small quantity of charcoal by blowing in moderate blasts, and the gold and silver as well as the copper and lead separated. Then the copper was subjected to liquating and the lead to the old Japanese cupelling process for the gold and silver contained in them.

Metallurgy Introduced after the Restoration :—The ores are divided into two sorts, the auro-argentiferous and the argenticupriferous ore. The former is treated by the barrel-amalgamation process and the latter smelted in a Raschette furnace.

The Barrel Amalgamation. The richer ore is pulverized by means of iron stamps brought from California, and the poorer is cleansed in the Rittenger horizontal vanner. A reverberatory furnace receives these two kinds of ore suitably mixed with regard to the quantities of sulphur they contain together with a certain quantity of common salt. The silver thus converted into the chloride is allowed to cool, trommeled, and then put into cast-iron barrels, in

which it is made to revolve with suitable quantities of mercury and wrought-iron balls. The chloride yields its silver after a time and the latter combines with mercury to form an amalgam. This amalgam is now highly heated in a retort and the mercury escapes. The free silver after being fused and refined in crucibles made of graphite is cast into ingots. The surplus mercury is purified by means of a press.

The Smelting Process. The better class of argenti-cupriferous ore (The inferior sort is not worked, at present, but remains to be worked after the completion of the concentrating apparatus) is broken into about one inch pieces. More or less iron sulphite is mixed with it, as it contains more or less silica. The mixture is roasted to get rid of the sulphur, arsenic, and other admixtures it contains. It then goes into a Raschette furnace, together with charcoal and coke to be smelted and made into copper matte, which is treated as mentioned under " Metallurgy practiced before the Restoration."

A blowing machine is used in connection with the Raschette furnace.

Improvements in Metallurgy:—The improvements in the metallurgical operations were commenced last year (1891) and are not yet perfected. In the main they will be as follows:—

The ores from the mine are first thrown on grates. The coarser portion remaining on the grates, goes to rock-breakers, and thence to trommels, and is assorted into three sizes A, B, and C of which the first two fall on revolving concentrators and are slowly carried forward. In the meantime girls sitting on both sides of the concentrators assort the ores into several grades. The finer portion is carried into slime-pits by a current of water and is made to rest there until it comes to be worked. The ores thus dressed return to the rock-breaker to be made still finer and then are pulverized in a Huntington mill (in which there is mercury for absorbing the native gold and silver in the ores). From here they are carried in improved

launders in a current of water. The sands and slimes flow into pointed boxes, and there deprived of the surplus water, are poured into Frue vanners which remove the coarser sands. Even after these repeated cleansings and concentrations some metallic portions remain in the sands, which therefore are made to run over Linkenbach buddles before they are permitted to rest in the slime-pits.

The ores treated as stated above are divided into two classes, in accordance with the quantities of precious metals they contain. The richer class is treated by a dry method, and the poorer by a wet process.

Treatment of the Richer Class. The richer ores are roasted with a suitable proportion of the lead ore, and after desulphurization is completely effected, they are partly fused by strongly heating them. The partly fused mass is taken out of the roasting furnace and permitted to cool. By the time it has sufficiently cooled, a water-jacket furnace is made ready to receive it together with flux and coke. The lead is freed and absorbs the precious metals.

Treatment of the Poorer Class. The inferior grade of ores is first deprived of the excessive moisture it contains by drying it in a Stetefeldt ore-drying furnace. After that, it is mixed with suitable quantities of iron pyrites and common salt and roasted in a reverberatory furnace. From this furnace it is taken out after it is sufficiently roasted, and allowed to cool. After cooling, it is thrown into a tub in which the soluble metals in it are washed out by means of warm water. This water is led into a trough filled with wrought-iron filings, as it contains a little gold and copper. Next a solution of hyposulphate of sodium is poured into the tub containing the ore. The precious metals dissolve and the solution flows then into a pail in which after adding a certain quantity of sodium sulphide precipitation takes place. The liquid from which gold and silver have been removed by precipitation is made to run into a reservoir from which it is returned to a pail placed above the reservoir. It is here kept for further use. The precipitate is raised up in a small pail from which it is poured into a press. The press deprives it of the liquid it contains. It is then dried and sent to Osaka to be refined.

The improvement in the treatment of the copper ore is as yet only under consideration.

Supply of Fuel:—There are many extensive forests in this district, but of late they have been greatly thinned to meet the general increase of demand for fuel in recent years. Wood is thus worth more than double it was six or seven years ago. It is now the intention to restore the thinned forests to their former state. Coal therefore is used in the roasting, and coke in smelting furnaces, fuel from the forests only being used in unavoidable cases.

Percentage of Extraction:—

By the Barrel Amalgamation......	Gold.........	60.800 %
	Silver	72.061 „
By the Smelting Process	Silver	63.546 „
	Copper ...	76.025 „

The numbers show the percentage extracted from the dressed ores. So much has been obtained under the old system. How much will be extracted under the new system can not yet be stated, for the improvements planned are not yet completed.

Production Statistics:—The production since the improvements above stated have been commenced are about as follows per year:—

Gold	about............	26	kilogrammes.
Silver	„	3,251	„
Copper	„	13,300	„

Cost of Working:—This has been as follows under the old system:—

Barrel Amalgamation......	5.847	*yen* per 1,000 kilog. of ore.
Smelting Process	17.751	„ „ „ „ „ „

Use of Steam, Water etc. as Power:—Water is led to the mill in wooden pipes from a distance of about two miles and is

made to move two Lisdon water-wheels (100 horse-power). These run the various metallurgical machines and are also used to generate electricity, which is used to illuminate the various parts of the mill. Thus the claim is very fortunately situated as regards water.

For crushing ores, repairing machines and implements, and for transporting things up and down the shafts, steam-engines (50 horse-power in all) are used.

Transportation :—Railroads are built both in and out of the mine and on them wooden wagons each about 1,700 kilogrammes capacity are drawn by men in to the pits and by horses out of them.

The shafts are provided with cages and wire ropes.

The rails used weigh ten pounds to the yard.

Distances to Markets :—The distances to some of the principal cities and towns in the nighborhood are as follow :—

To Himeji............................	26 miles.
,, Shikamatsu........................	28 ,,
,, Kobe	65 ,,
,, Osaka	86 ,,

From the mine there runs a good wagon-road, built years ago at a cost of more than 70,000 yen, to the port of Shikamatsu where there are store houses belonging to the mine. From the port mentioned, steamers sail to Kobe, Osaka, and other ports. On land Kobe and Osaka are easily reached by the railroad from Himeji.

The produce of the mine is sent to the Branch Office at Osaka to be refined and sold.

Materials needed in the mine are bought in Osaka and Kobe.

INNAI SILVER MINE.

Situation :—The Innai Silver Mine at Innai Village, Okachi-gori, Ugo Province, Akita Prefecture, is on the southern boundary of the province of Ugo, 72 miles south of Akita, 67 miles north of Yamagata, and 12 miles west of Yuzawa. Yuzawa, which has 1,587 families and 7,516 inhabitants, is the nearest market to the mine.

The Kami and Shimo Innai villages contain together 504 families and 1,571 inhabitants. Ascending a mile westward from the Kami Innai Village is the Nagakura mill, and two miles west there are the mines and Ginzan-Machi where there are 579 families and 2,376 inhabitants.

General History :—The outcrops, it is said, were first seen in 1596 by one Usui Shichiro-zaemon of whom little is known. In 1607 Murayama Sōbei, a vassal of Otani Yoshitaka, the feudal lord of Tsugaru at that time, came as a refugee to this district after the battle of Sekigahara and took up his abode in the village of Ono in Okachi-gori. A band of miners, who were then rambling about this neighborhood, were overheard by him, while talking about the existence of silver ores in the mountains some seven miles from the village where he had settled. He determined if possible to discover these deposits. It was not long before he finished the preparations for his journey to this land of promise and set out. Beyond Nagakura no path was before him. Steep rocks and thick forests were plentiful. But he, a warrior, was not at all daunted. He plunged into the dense brushwood and had gone a few hundred steps, when a

waterfall,—perhaps the one now called Fudōdaki—met his sight. Scrambling a few hundred steps along the side of the cataract, what surprised and delighted him was the sight of a silver vein. After that, he apparently worked it a great deal, for there are many buried pits at Nakayama, which is supposed to be the site of his discovery. It is said that the work he started experienced great and frequent turns of fortune, but nothing certain has come down to us. From somewhere between 1801 and 1803 the output became gradually less until 1807, when it increased a little. Who were the proprietors of the mine and what were the methods of working at that time, no one knows now, but it is thought that no great capitalist owned it and the miners worked on their own account. In 1817 Satake, the former lord of Akita, had the mine transferred to him and until some years after the Restoration, it was worked by his vassals. Between 1830-1844 the produce was so great, that for more than ten years in that period, a monthly output of 100 *kwamme* was obtained. In May 1873 the Kōzan-Kuwaisha took the claim into its hands, but a year after, transferred it to the Ono Co., who after a few months on account of their failure gave it up. In December of the same year, the Akita Prefectural Government with the consent of the Treasury Department resumed the work. In 1875 the Ministers of the Treasury and of the Public Works Department thought it best to entrust the management of the mine to the Mining Bureau of the latter Department and this, with the permission of the Minister President of State, they did. A branch office of the Mining Bureau was established at the mine and on the first of November 1875 the new commissioners resumed work. In 1878 the Government raised the Industrial National Loans for improving mining work thoughout the whole country. Of the money thus raised, this mine received a little over 400,000 *yen* and on November 19th, 1879, the work of improvement was set agoing. Four foreign engineers were hired; the roads were repaired and the metallurgical work was greatly improved.

On September 21th, 1887, this mine was honored by a visit from His Majesty the Emperor while on his progress through the Hok-

kaidō, Akita, and Yamagata districts. Led by Yoshii Tomozane, then First Vice-Minister of the Public Works Department, and followed by Fukushima Banrō, then the Director of the Mine, the Emperor examined the Ogiri adit level mouth, the dressing house, the mill, etc.

The improvements were completed on June 30th 1881.

In December, 1884 the present lessee, Furukawa Ichibey, had the mine transferred to him from the hands of the Government. He introduced improvements in various departments and the mine up to the present, is very prosperous. The vicissitudes of fortune it experienced since somewhere between 1804 and 1818 up to the present, can be seen in the table of productions.

Geological Formation, Ore Deposits; and Character of Ore:—The containing rock is the hard Tertiary tuff, there are several veins but two of them only are at present worked, one thick and the other thin called Hondate. They strike from east to west and dip 70 to 80 degrees northward. They are about 5,000 feet long and from 2 to 12 or 13 feet wide.

The chief ores are stephanite and myargyrite containing 0.1 to 0.02 % of silver. The veinstuffs are chiefly feldspar, quartz, and calcite.

Depth of Shafts and Length of Levels:—The depth of shafts and the length of levels are given in the following tables.

A. Shafts.

Shafts.	Width.	Length.	Depth.	Remarks.
Yamaichi Shaft	14	6	485	——
Ainoyama "	12	4	460	——

B. Levels.

Levels.	Height.	Width.	Length. of Level.	Remarks.
	ft.	ft.	ft.	
Ogiri (drainage level)...........	9	8	8,170	——
No. 1 Level........................	7	4.5	1,520	——
No. 2 „	Abandoned.			100 feet from No. 1 to No. 2 level.
No. 3 „	7	4.5	2,466	140 feet from No. 2 to No. 3 level.
No. 4 „	7	4.5	1,896	100 feet from No. 3 to No. 4 level.
No. 5 „	7	4.5	1,068	100 feet from No. 4 to No. 5 level.
No. 6 „	7	4.5	90	100 feet from No. 5 to No. 6 level.
Hayabusa Level	7	4.5	2,292	——
Kifuku and Chitose Levels ...	7	4.5	1,056	——

Cost of Mining :—The cost of mining one ton of ore (1 ton = 270 *kwamme*) containing, on an average, 0.0435 % of silver, is about 5.187 *yen*.

Metallurgy practised before the Restoration :—The ores after being mined were taken home by each miner, broken into pieces about the size of a finger, washed and sorted. The best of them was called *sashi* and the poorest *dashi*. Besides these there were two other sorts, one called *damono* and the other *komagari*. The *damono* was prepared mostly by females in the following manner. In spring and summer the mud in the canal outside the house of each miner was dredged out and washed by passing it through a current of water in a pipe about one foot in diameter, ten feet long, and lined with coarse cloth. The pipe was laid a little slanting. The water washed away the lighter mud and sands, while the heavier metallic portion remained in the cloth. The cloth was afterward washed in a pail, and the ore i. e. the *damono* was obtained. What was called *komagari* was nothing but the powdered ore produced while breaking the rocks and

dressing the ores at the miner's home. The *damono* and *komagari* were richer in silver than the above mentioned ores.

The ores dressed as above stated were taken to the smelting works where there were twenty smelting hearths and as many cupellation furnaces which gave employment to over eighty workmen. The hearths were 1 foot in diameter and 0.25 feet deep. The forward part of the tuyere which was plastered with a mixture of powdered charcoal, clay, and water, and hardened by means of wooden hammers and also by the use of hard charcoal, received the argentiferous lead. The tuyere was made in the middle portion of the chimney, and was 0.35 feet wide and 0.06 feet high. The bellows 4.5 feet long, 2.4 feet high, and 0.95 feet wide were placed 0.8 feet behind the chimney. The charge this hearth received was as follows:—

1 *kwamme* of ore—containing over 0.1 % of silver: the ore containing 0.05 % silver was the poorest worked.

1 *kwamme* of slag—containing over 0.1 % of silver: the residue left after working the ore once or twice.

500 *kwamme* of hearth slag—called *Ichimai*: the litharge from desilverization hearths and containing some 300 *kwamme* of lead.

200 *kwamme* of lead.

300 *kwamme* of iron pyrites.

200 *momme* of common salt.

100 *kwamme* of iron scraps—used where the ore was highly silicious.

The *damono* and *komagari* were made into lumps and used as substitutes for ordinary ores.

The hearth being perfectly dry, ignited charcoal was put in; over it the hearth slag and lead were placed; over them about 300 *kwamme* of charcoal; and upon these a mixture of ore, slag, and iron pyrites was heaped. Next the bellows were started. As the

charcoal ignited, the larger pieces of it and the dropped portion of the ore were raised upward by means of iron shovels. These shovels were 0.4 feet wide, 0.5 feet long, and 0.015 feet thick. The handle 0.15 feet in diameter, made up of metallic and wooden portions, the former of which was 2.5 feet, and the latter 7 feet long. Fusion was usually effected in about 25 minutes. After this the larger pieces of charcoal were gradually removed by means of the shovel above described at the same time stopping the bellows. Some time after the remaining charcoal had been removed, water was sprinkled upon the fused mass and the matte was stripped off as it solidified. The argentiferous lead was conveyed into a hole dug in the ground near the hearth, by means of a ladle, 0.4 feet in diameter, 0.1 feet deep, 0.015 feet thick with a handle consisting of iron and wooden portions, the former 2 feet, and the latter 4 feet long. The hole was lined with a mixture of equal parts of powdered charcoal and clay. Out of the charge above mentioned about 700 *kwamme* of argentiferous lead were usually produced.

The whole of the argentiferous lead thus obtained was put into a desilverization hearth made of leached ashes, 0.7 feet in diameter and 0,2 feet deep. The bottom was covered with about 0,001 feet of animal charcoal. First, ignited charcoal was placed in front of the tuyere. Then, 500 *kwamme* of larger pieces of hard charcoal were arranged in rows upon the argentiferous lead already placed in the hearth and a small bellows 2 feet long, 0.5 feet wide, 1 foot high, and placed 1 foot away from the hearth, was set working. As the heat increased a part of the lead escaped up the chimney in white fumes and the remaining part was absorbed by the hearth bottom, so that in about 40 minutes, nothing but some 30 *momme* of silver and 700 *momme* of slag (containing some 60 % of lead), were left in the hearth.

Metallurgy Introduced after the Restoration:—Until December 1883 the methods above described were followed without any remarkable alteration.

In June 1886 while the mine was yet under Government management, the cholorination process then used having proved unfit for the ore the mine yielded, was abandoned, and the pan amalgamation process was adopted. Six pans were first made and subsequently six more two in October 1888, two in April 1889, and two more in April 1891, so that there are now twelve pans besides six settlers.

With the increase of the amalgamation pans, the crushing appliances were also increased, so that, while there were only 10 stamps under the Government, there are now 78 stamps and 4 Huntington mills.

The residue left after the completion of the amalgamation process contains some mercury and a minute quantity of silver. It is therefore worked by 12 Duncan concentrators first; and next by 21 Duncan concentrators and lastly by 14 Frue vanners. The concentrated portion is subjected to roasting and smelting processes.

Although the chlorination process was once abandoned, a good method of working the poorer and the vanned ores in accordance with that process having being discovered a roasting furnace was built in March 1889. Since then a great improvement in the procedure of work as well as in the construction of the furnaces, has been achieved. Now six furnaces of the new type are doing highly well. The tanks were also improved, those used at first being only one-third as large as those used at present. We have now sixteen of them, each holding 1,000 *kwamme.*

The ore treated by the Duncan concentrators and freed from quicksilver, is now worked as follows :—It is first made into matte by melting it with iron sulphide, limestone, old slag, matte and slag from matte roasting hearths, etc.

The matte thus obtained is roasted in a pot and then converted into argentiferous lead in a matte smelting furnace. The argentiferous lead is then worked in English cupelling furnaces. Two smelting and as many cupelling furnaces are now in use for the treatment of this kind of ore.

Fuel :—The fuel needed per year is as follows :—

Wood	21,094 cords.
Charcoal	3,300 tons.
Coal	1,200 tons.

The coal used at this mine is produced in, and brought from Mitsumori, Yamuki village, Mogami-gori, Yamagata Prefecture.

The mine can obtain the following quantities of wood supplied from villages within the radius of 12 miles, for the number of years given in the following table :—

No. of Years.	Wood in *tana*.*	Village.	County.	Prefecture.
12	222,000	Akinomiya.	Okachi.	Akita.
1	18,500	Takamatsu.	"	"
3	55,500	Sendō.	"	"
3	55,500	Sasako.	Yuri.	"
5	92,500	Nozaki.	Mogami.	Yamagata.
1	18,500	Nakada.	"	"
25	462,500			

Production Statistics :—The following are the production statistics for 1891 :—

Dressed Ore	78,113,772,000	*kwamme.*
Stamped Ore	72,402,671,000	"
Silver Amalgam	190,656,800	"
Amalgamation Residue	49,976,781,000	"
Concentrated Ore	14,847,071,000	"
Vanned Ore	513,410,000	"
Roasted Ore	40,068,043,000	"
Precipitation Process Material	40,068,043,000	"
Precipitated Silver	17,935,852	"

* 1 *tana* = 10 × 10 × 2.5 feet.

Matte from Smelting Furnaces......	714,624,000	*kwamme.*
Cupelled Silver	5,446,450	„
Refined Gold...........................	138,066	„
Refined Silver	32,308,093	„

Percentages of Extraction :—70 % by the pan amalgamation process and 20 % from the amalgamation residue, i. e. 90 % from the original ore.

65 % by the Augustine chlorination process.

90 % from the matte produced in smelting furnaces.

Cost of Metallurgical Work :—

Amalgamation	2.66	*sen* per	1	*momme* of refined silver or gold.
Precipitation	8.63	„ „	1	„ „ „ „ „ „
Smelting	9.25	„ „	1	„ „ „ „ „ „
Concentration	80.77	„ „	100	*kwamme* of ore.
Stamping	42.42	„ „	100	„ „ „

Transportation :—Underground there are single and double line railroads. The rails used are of the T pattern and weigh 11½ pounds to the yard. The gauge is 1.7 feet. On these roads ore laden wagons each 150 *kwamme* capacity are hauled by laborers when the line is single and where double, by horses. The whole line measures 23,230 feet.

On the surface similar rails and gauge are employed measuring 14,995,2 feet in all. Both wooden and iron wagons are used. They are each 200 *kwamme* in capacity. Where there are no railways, ordinary hand and horse wagons are used.

A wire-rope tramway 2,730 metres long has been constructed from Nozaki village, Mogami-gori, Yamagata Prefecture to Hiyamizu in Innai village, Okachi-gori, Akita Prefecture, a distance of about five miles.

Production Statistics:—

STATISTICS OF GOLD PRODUCED FROM THE INNAI MINE DURING THE LAST SEVEN YEARS, FROM 1885 TO 1891.

Year.	Gold in oz.	Year.	Gold in oz.
1885	33	1889	1,261
1886	562	1890	1,702
1887	1,103	1891	1,678
1888	1,066		

STATISTICS OF SILVER PRODUCED FROM THE INNAI MINE DURING THE LAST SEVENTY FOUR YEARS, FROM 1818 TO 1891.

Year.	Silver in oz.	Year.	Silver in oz.	Year.	Silver in oz.
1818	11,080	1843	129,864	1868	38,819
1819	12,291	1844	93,194	1869	38,286
1820	8,903	1845	36,900	1870	47,416
1821	11,442	1846	39,695	1871	50,893
1822	11,264	1847	91,986	1872	46,413
1823	28,753	1848	64,678	1873	44,983
1824	47,143	1849	58,382	1874	42,224
1825	37,632	1850	54,120	1875	48,766
1826	37,850	1851	44,617	1876	57,413
1827	49,700	1852	54,394	1877	55,948
1828	65,341	1853	50,925	1878	48,451
1829	64,375	1854	46,759	1879	50,009
1830	56,878	1855	85,870	1880	31,376
1831	46,425	1856	65,650	1881	21,824
1832	47,240	1857	97,819	1882	25,987
1833	143,253	1858	63,651	1883	88,866
1834	170,120	1859	71,427	1884	77,378
1835	163,558	1860	95,370	1885	101,056
1836	132,657	1861	65,789	1886	142,936
1837	141,904	1862	85,144	1887	164,783
1838	174,830	1863	37,860	1888	183,328
1839	139,776	1864	31,092	1889	220,657
1840	155,424	1865	35,780	1890	339,637
1841	123,700	1866	38,987	1891	394,434
1842	140,035	1867	45,593		

Boilers Engines, etc:—

Ainoyama Shaft 1— 25 H.P. Root's Boiler and 1—20 H.P. Winding Engine.
Yamaichi Shaft 5—250 H.P. Boilers and 1 Winding Engine.
Drainage Shaft 1— 10 H.P. Boilers and 1— 4 H.P. Winding Engine.

Dressing Work	1— 25 H.P. Root's Boiler 1— 20 H.P. Double Eccentric Steam Engine	for 1 Large Crusher. for 3 Small Crushers. for 2 Trammels.
Stamping	1—35 H.P. Root's Boiler 1—25 H.P. Vertical Steam Engine	for 20 Stamps.
	1—25 H.P. Root's Boiler 1—20 H.P. Vertical Steam Engine	for 10 Stamps. for 2 Huntington mills.
	1—40 H.P. Turbine	for 30 Stamps.
	1—40 H.P. Boiler and 1—40 Horizontal Steam Engine	for 2 Huntington mills.
Amalgamation Work	1—40 H.P. Root's Boiler 1—50 H.P. Double Eccentric Steam Engine	for 12 Amalgamation pans.
	1—25 H.P. Root's Boiler 1—40 H.P. Horizontal Steam Engine	for 6 Amalgamation pans.
	1—25 H.P. Root's Boiler	for 10 Stamps.
	1—30 H.P. Boiler 1—30 H.P. Over-shot Water-wheel	for 12 Duncan Concentrators. for 2 Frue Vanners.
Concentration Work	1—25 H.P. Root's Boiler 1—16 H.P. Double Eccentric Steam Engine	for 21 Duncan Concentrators. for 2 Buckets. for 2 Centrifugal Pumps.
	1—15 H.P. Boiler 1—15 Horizontal Steam Engine	for 12 Frue Vanners. for 2 Centrifugal Pumps. for 2 Buckets.
Smelting Work	1—15 H.P. Down-shot Water-wheel	for 2—No. 3 Root's Blowers. for 1—¼ Root's Blower. for 1 Grinding Mortar.

Mechanical Shop 6 Sundry Engines.

HANDA SILVER MINE.

Position of the Mine :—The mine is situated in a mountain at Handa in Date-gori of Fukushima-ken, at the foot of which lie the villages of Handa and Kosaka. It is 174 miles to the north of Tokyo. It is conveniently located, being $1\frac{3}{4}$ miles to the west of Kori railway station. The mountain is 3,135 feet high being the highest in the neighborhood. It is connected with the range of mountains running between it and Honshu from north to south like a backbone; in the west it gradually decreases in height at Yonezawa and towards the east at the river Abukuma, which is five miles away. The mine covers an area of 587 acres 32 perches.

General History :—Though the mine is said to have been discovered about 806 A. D. yet as there is no record of it, we do not know the exact date, but the old workings below and the out-crop of the mine are so extensive that there can not be any doubt of its having been worked for several hundred years before we had knowledge of the use of explosives and the advantage of railway transportation. We have reliable records of the mine dating as far back as 1596 and during the fifty years between 1608 and 1658 it was very productive. In 1661 it was worked by Uyesugi Harima-no-kami Tsunakatsu, a feudal lord, but it can only have been for a few years, as in 1664 he gave up the land in this district.

After that time for about 40 years, the mine was worked but little, the ores being only extracted by neighboring farmers during their leisure hours. Since 1704, when Matzudaira Shoū, a feudal lord came to the district, several levels in the mine were actively worked, but no good ores were found, and at last the mine was transferred to the Tokugawa Government.

The date when the Tokugawa Government began to work the mine is unknown, but the first record of silver bullion being produced is in 1747; hence its workings must have been undertaken somewhere about 1742.

Since that time the mine was continuously worked for 122 years by the Tokugawa Government, but they ceased working in 1864. In 1867 a rich farmer, Den-no-suke Hayata of Handa village began to work the mine again, but the ventilation of the mine being imperfect he together with 13 hands of miners were suffocated by carbonic acid gas. This was in 1870 and the workings were again abandoned. In 1874 Mr. Tomo-atsu Godai, the late father of Riusaku Godai the present owner, began to work the mine, and up to the present, No. 1, No. 2, No. 3, Nikaihira, and Saiko adit levels have been opened, all of which were old workings almost entirely broken down by age, ten years having elapsed without any care given to the woodwork of these levels since the Tokugawa Government were engaged upon them. Since 1874 these adit levels reached the vein at various dates as shown in the explanation of the following table. But excepting the Saiko adit level (the lowest) the ores in the upper part of the vein were found to be entirely taken out by old workings. Great efforts were therefore made to open the Saiko adit level. In January 1883 the Honban vein was reached. Beyond this vein, there is a vein called Dōshiki at a distance of about 280 feet westward, as is described in the section relating to ore deposits. This has yielded the greatest part of the ore. In order to reach this Dōshiki vein, a westward cross-cut on the hanging wall from the Honban vein was made, and at about 110 feet from this cross-cut a vein of rich silver ore with a large proportion of zinc blende and with a slight percentage of gold, was unexpectedly met with. This is called the Kamewaka vein and its width which is about 5 feet was entirely filled with rich ore. Such a bonanza was never known before in this mine.

In the table given below, the silver bullion got from ore before 1887, came entirly from this Kamewaka vein, and after that date the ore from Dōshiki vein supplied about half the product.

Discovery of rich Tailings:—While the openings of these adit levels were carried on, the dumps which had accumulated to form several hills outside the mine during the period since its opening, were washed and repicked, and at one time near the root of a tree a curious fine brownish layer of mud was discovered. By assay it was found to contain from 0.60 to 0.08 % silver.

This was afterwards found to be the old tailings of ore which escaped from settling on a rough cotton cloth, called *Nekonagashi*. The *Nekonagashi* was a rude concentrating flume-like apparatus on which all ores whether rich or poor had to flow over in water having been previously ground by millstones. These tailings were found in great quantities and varied in depth from 5 inches to 20 feet. The total quantity treated in the mill was over 42,000 tons of 2,000 pounds.

The treatment of the old tailings began in 1880 and was almost finished in 1887. This discovery of these valuable tailings caused considerable sensation resulting in several similar, but less important discoveries in many other old silver mines. In the following table the quantities of silver bullion produced since 1875 are given:—

Years.	Silver bullion containing about 1 % of gold produced from ores in ounces.	Silver bullion containing about 1 % of gold produced from old tailings in ounces.	Sum of Silver bullion in ounces.	Price in *yen* 1.44 *yen* being equal to $ 1 at the rate of exchange of April 1892.
1875	2,958	—	2,958	4,580.014
1876	9,226	—	9,226	14,285.866
1877	3,733	—	3,733	5,564.239
1878	4,738	—	4,738	7,036.293
1879	8,199	—	8,199	15,361.220
1880	8,248	9,117	17,365	37,968.480
1881	—	60,873	60,873	145,125.358
1882	—	126,918	126,918	270,182.248
1883	—	158,026	158,026	275,111.000
1884	105,322	121,536	226,858	331,417.668
1885	45,070	58,170	103,240	150,938.233
1886	35,086	7,771	42,857	62,507.091
1887	48,595	5,767	54,362	84,324.086
1888	65,577	—	65,577	98,835.155
1889	64,683	6,520	71,203	114,504.762
1890	45,080	6,782	51,862	83,520.231
1891	50,741	3,378	54,119	83,807.031
1892 till Feb. 28th	12,669	212	12,881	unknown.

Geological Formation:—The geological structure of the mine sett has not yet been accurately ascertained, but it seems to be of the Tertiary System. The principal rocks found in the Handa mountain are tuff sandstone, conglomerate, and breccia, formed of liparite, augite, and andesite. The breccia is most abundant on the west side of the vein which runs throught the tuff sandstone.

Ore Deposits:—Ore is deposited in a regular fissure vein which runs from north to south. It dips between 40 and 60 degrees westward. The inclined distance from the outcrop to the present working floor is 2,530 feet and the length of the vein from the northern to the southern extremity is over 3,000 feet. At the level somewhere about Saiko adit level, the main vein is divided into three branch veins of which the east one is called the Honban vein, the middle one Kamewaka vein, and the west one Doshiki vein.

The vein stuffs of both Honban and Doshiki veins are quartz, calcite, and clay; and the veins are from 3 feet to 20 feet wide. Ores are generally found in quartz, but sometimes in clay; they are argentites and occur in mere streaks or bands of about one foot wide. The Kamewaka vein affords a strikingly different appearance from the other two veins, it being almost entirely filled with quartz and calcite, clay being very rarely found. Ores are found in quartz in bands from 5 inches to 5 feet wide. As much as 20 % of zinc blende is found in the ore.

The dip of these three veins are similar and no fault of any magnitude has been met with.

Quality of Ores:—Though the ores contain copper, lead, and zinc, besides silver and gold, yet the former three metals are neglected, gold and silver being only extracted. As is mentioned under the section relating to Ore Deposits, the ores from Doshiki and Honban veins are argentites with less than 5 % of zinc blende. The ore from the Kamewaka vein contains a much greater quantity of zinc, other things being almost equal; both ores contain a slight quantity of gold. In

the Doshiki and Honban veins pieces of pure argentite weighing from ¼ ounce to 10 ounces are sometimes found.

The rich ore contains 8.5 % of silver and the poor only 0.04 to 0.05 %. In the Kamewaka vein a thin foil of native silver is sometimes found. The rich ore contains 6 % of silver, and the poor 0.005 %. In these three veins ores containing less than 0.05 % of silver are very scarce, and the average quality of milling ore generally comes to 0.2 % of silver.

One of the samples is the ore from the Doshiki vein and the other from the Kamewaka vein.

Shafts and Adit Levels:—The depths of inclined shafts and the length of adit levels are given in the second table of explanation about exhibits and also in the next section.

Transportation:—The first, the second, and the third adit levels are for ventilation and as a means of escape in case of emergencies, Both the Saiko and Nikaihira adit levels are solely used for transportation and are laid with portable railways for a length of 9,100 feet in the former and 4,100 feet in the latter. Horses are used for drawing wagons. The wagon is 1 foot 6 inches high, 1 foot 10 inches wide and 3 feet in length and is made of wood strengthened with several iron ribs; its capacity is 666 pounds, and 15 of these wagons are drawn by one horse, so that one horse can draw 5 tons, and as the horse can work three times in a shift of eight hours, six horses in 24 hours can bring 90 tons out of the mine. Below this adit level along the vein, inclined railways with double lines are laid, up to which ores and rocks are raised by a hand windlass.

Expense of Mining:—The average expense of mining 826 pounds of ore is 7.15 *yen*. As is remarked under the head of Ore Deposits, the veins are quite regular and faults are rarely met with, and ores are generally followed in streaks or bands. Even in prospecting work, ores are got more or less, and the above average expense includes everything pertaining to works in the mine.

Position of the Mill:—The mill is situated about 720 yards up the stream near the Saiko adit level, and though inconvenient for the transportation of ores up the gradually sloping road on the one hand, yet on the other hand there is the great advantage of utilizing water power for the mill.

Ancient Metallurgy of Silver and Gold:—In order to get rid of quartz, calcite, and other vein-stuff from ores, all the ore was broken with hammers then ground by a millstone in water and finally concentrated by running it down over cloths.

The concentrates ran as high as 10 % of silver. These were made into small balls mixed with charcoal powder, and were smelted with charcoal for silver and gold.

One charge was 41 pounds of concentrates, the richness of which having been judged by an experienced eye, for every 12 ounces of silver supposed to be in the concentrates sixty ounces of lead were added and the charge was put in a smelting hearth built in the ground. The hearth was circular, 1 foot in diameter, and 5 inches deep in the centre. Behind the hearth a hand blower was set, and air was blown on the surface of charcoal fire and the smelting effected. The matte contained gold, silver, copper, lead &c. which were subjected to cupellation for obtaining gold and silver.

Present Metallurgy of Silver and Gold:—At present the Freiberg barrel amalgamation is used for the extraction of gold and silver. Ten dry stamp batteries are worked by an overshot water wheel 23 feet in diameter, and 20 dry stamp batteries are worked by a Girard turbine with partial openings. About 9 tons of ore are csushed in 24 hours after which it goes to the chlorination furnace.

The chlorination furnace consists of an ordinary reverberatory furnace 47 feet long and 11 feet wide, and for every 826 pounds of ore, 50 pounds of common salt are added. After 10 to 12 hours of stirring on the hearth before a gentle fire, the ore is taken out of the hearth and left in heaps for some time to assist the complete chlorination. It is then sent to the barrels.

The amalgating wooden barrels are of two sizes, the larger ones have a capacity for 1,652 pounds and the smaller ones for 826 pounds. There are four of the former and five of the latter. In the smaller barrel 661 pounds of ore and 66 pounds of mercury and in the larger one 1,488 pounds of ore and 148 pounds of mercury both with a proper quantity of water, are put in, and the barrels are revolved for 10 to 12 hours, after which an assay shows the degree of amalgamation. The charges are then taken out and the mercury is strained through a deer skin and the amalgam is caught in the strainer, of which about 15 % is silver and gold, and the remainder mercury, copper ,iron, and other impurities.

The amalgam is put in a cast-iron retort, and gently heated when the mercury is condensed and caught in cold water. The resulting product left in the retort usually contains about 70 % of silver and gold, the rest being copper, iron, and other impurities. Usually the product is then melted in a crucible and cast into ingots ready for market, but when its fineness falls below 75 % of silver, it is refined in a cupellation furnace.

Improvement in Barrel Amalgamation:—Formerly cast-iron balls or old scrap iron were put in the barrel, but as they wear down the barrel very soon, 15 of 1 ¼ inch round bar iron in the small barrels and 20 in the large barrels are fitted up axially but following a spiral. The result of amalgamation is just as good as before, if not better, and the life of a barrel is more than three years or it lasts 18 times as long as it did with iron balls or scrap iron.

Percentage of Extraction:—Ores from the Doshiki and Kamewaka veins are mixed in proper quantities and are treated for amalgamation.

In 1891 the silver produced amounted to 81 % of the assay of the ore.

Expenses of Milling:—In summer and winter, the water power is considerably reduced in quantity and steam power is used. This increases the expense of milling in the dry season, but the

average expense of milling throughout the year is including everything 2.739 *yen*.

Use of Water and Steam Power:—Girard's turbine with partial openings used for dry stamp batteries usually gives 22 horse power, but in the dry seasons it is reduced to only 8 horse power. In order to assist the turbine at such times a 20 H.P. Cornish boiler and a 15 H.P. high-pressure steam-engine are used.

The amalgamation barrels are usually revolved by a 6 H.P. overshot water-wheel, which is supplemented by a 16 H.P. Westinghouse engine and boiler.

Fuel:—The fuel is principally of wood and is very scarce. It comes from a distance of 12½ miles in carriages drawn by horses or oxen. One cord of wood costs 4.15 *yen*.

Distance from Markets:—About 1¾ miles east from the mill there is Kori railway station, and ¼ miles further there is a town called Kori having about 800 houses. About 10 miles south, there is the town of Fukushima, having 2000 houses where the district government of Fukushima-ken is situated, and where certain articles for the mine are obtained. Most of the chemicals and iron-ware are brought from Tokyo, 174 miles to the south, and where a railway line connects with Kori station. Silver bullion can be sent to Tokyo by railway in ten hours.

Analysis:—At present the ores are chiefly obtained from the Dō-shiki and Kamewaka veins. The ore from the latter contains much more zinc blende than the former. Their analyses are as follows:—

Dōshiki ore contains			Kamewaka ore contains		
Gold	=	0.093 %	Gold	=	0.009 %
Silver	=	8.000 „	Silver	=	2.069 „
Copper	=	1.230 „	Copper	=	1.200 „
Lead	=	8.240 „	Lead	=	12.000 „
Zinc	=	4.550 „	Zinc	=	20.000 „
Others are non-metallic.			Others are non-metallic.		

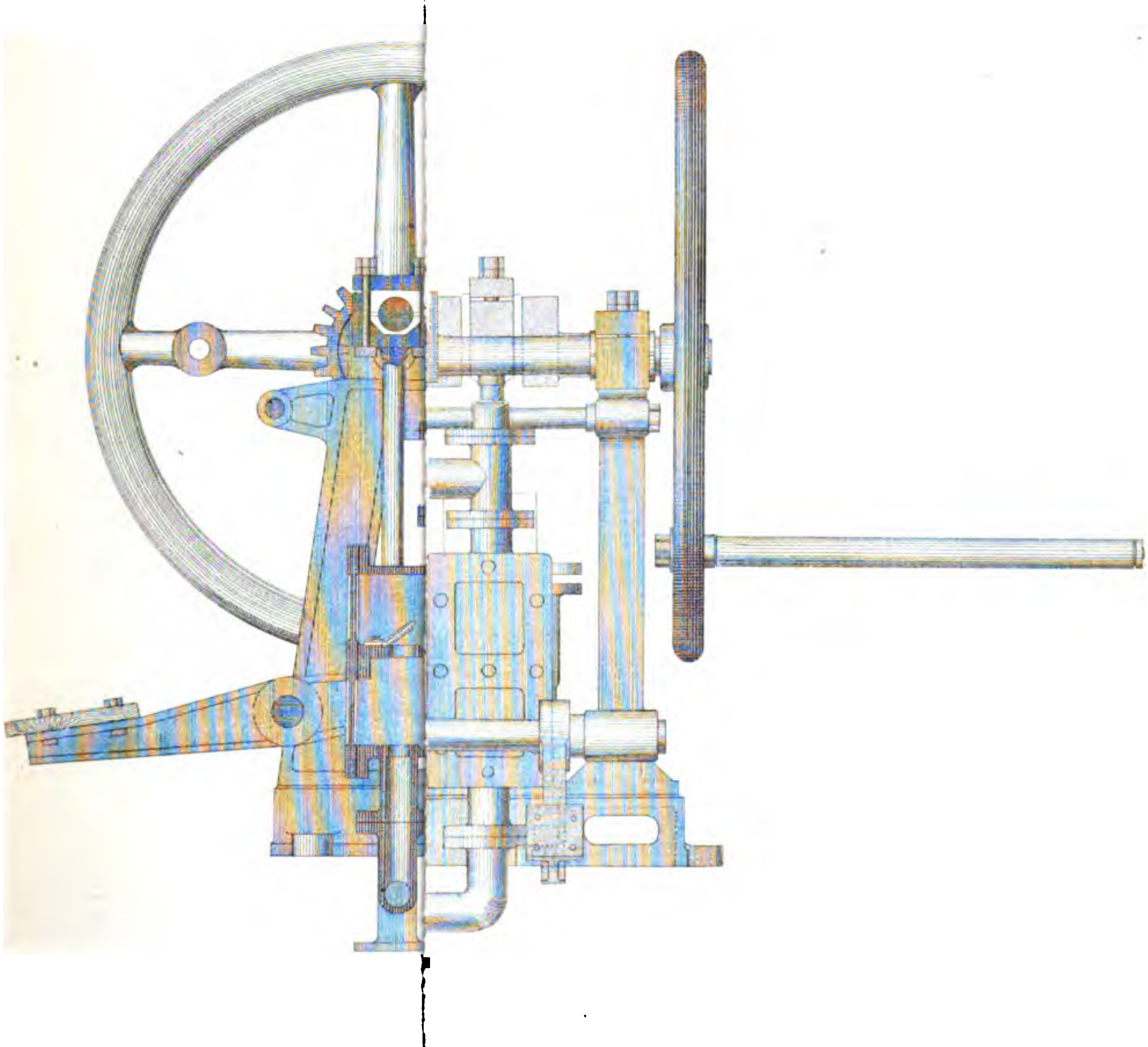
Levels :—The following table shows the length of levels etc.

Adit levels.	Date when opening of adit levels was commenced.	Dates when adit levels reached the vein.	Length of adit levels in feet.	Respective height of each adit level in feet.
No. 1 Level ...	unknown.	unknown.	627	——
Nikaihira	"	"	2317	105 ft. lower than No. 1 adit level.
No. 2 Level ...	"	"	1520	100 ft. lower than Nikaihira adit level.
No. 3 " ...	1786	1810	3741	373 ft. lower than No. 2 adit level.
Saiko	1830	1846	6371	253 ft. lower than No. 3 adit level.

Since the Tokugawa Government gave up the mine in 1864, the mine was left almost unworked for ten years, and all the adit levels were broken down. When the late Tomo-atzu Godai began to work the mine in 1874, and the following levers were added.

Adit levels.	Dates when adit levels reached the vein.	Length of adit level in feet.	Remarks.
No. 1 Level	Feb. 1875.	2550	Connected with Nikaihira and Saiko adit levels, and is used for ventilation and way for escape in case of emergencies.
Nikaihira	Feb. 1875.	4700	Connected with Saito and No. 1 adit levels and exploration and mining is now carried on.
No. 2 Level	Oct. 1875.	3500	Connected with Saiko adit level through No. 3 adit level and is now only used for ventilation.
No. 3 Level	Dec. 1878.	4800	Connected with No. 2 and Saiko adit levels and is now used for ventilation and way for escape in case of emergencies.
Saiko	Jan. 1883.	9131	Portable railways are laid thoughout the whole length, and used for transportation and water drainage. It is connected with No. 1, Nikaihira, and No. 3 adit levels and is now the chief working level.

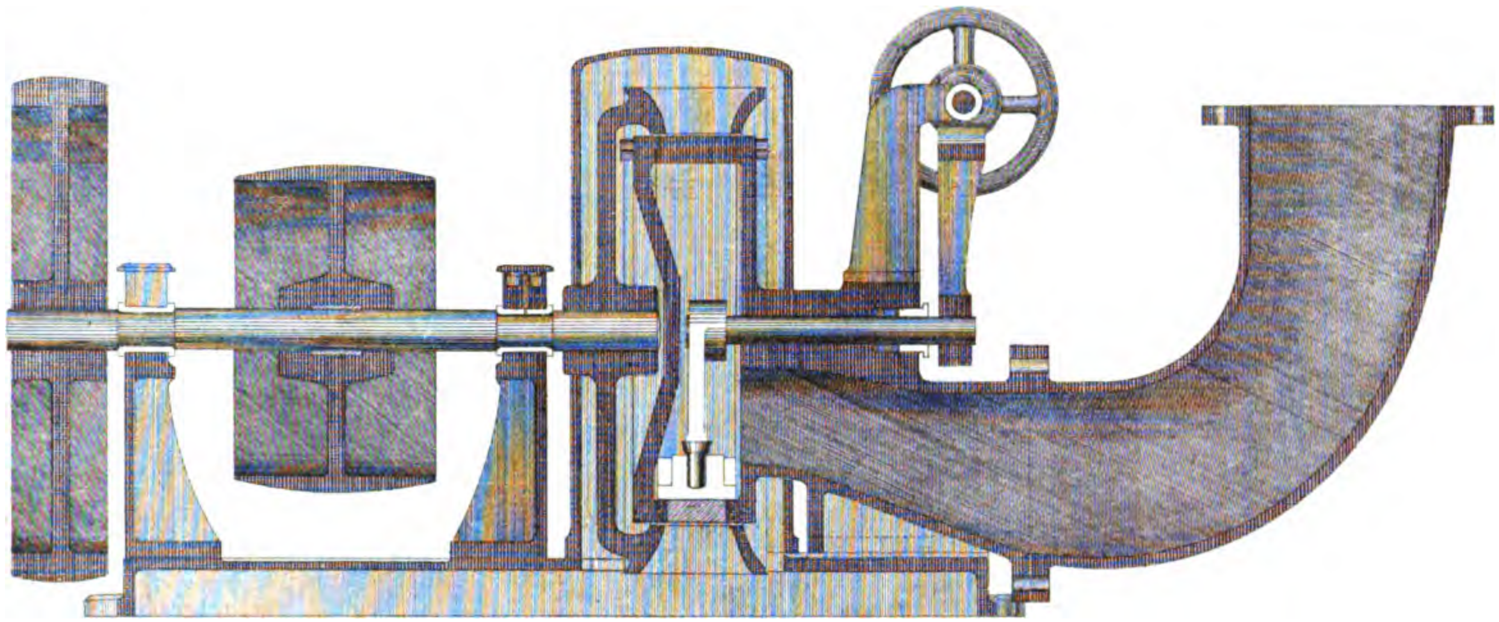
END VIEW.



GIRARD TURBINE

WITH

PARTIAL OPENINGS.



SCALE $\frac{1}{12}$ SIZE.

DESIGNED BY R. GODAI,
HANDA SILVER MINE,
JAPAN.

Pumps:—Hand and foot pump for use in the mine. One pump was designed by Riusaku Godai the owner of the mine. Special attention was paid for convenience, all of its parts being made of small pieces, so that there is no difficulty in taking them into the mine. It occupies 8 feet square and all the parts are firmly fixed on a cast-iron bed plate, so that there is no connection between its working parts and any external wooden posts which are liable to get out of order in consequence of yielding of the walls. The pump is worked both by hand and treadle and with twenty men it is capable of pumping 15,873 gallons of water in 24 hours though a vertical height of 220 feet in the Doshiki vein.

Girard's Turbine:—The wheel is used for driving stamp batteries. Formerly four overshot water wheels were used to drive four stamp batteries each at a distance of 80 yards. As this was very inconvenient it was proposed to build one large building in which all the scattered stamp batteries were to be gathered together, and the choice of a suitable water motor had to be made. Though the mountain Handa is very high, yet the valley is rather short and there are no forests near the source of the stream. The quantity of water to be utilized is very small, being usually 3.2 cubic feet per second which in summer is reduced to about one quarter of the amount. As the cam axis of the batteries had to make 32 revolutions per minute, it was necessary for the water motor not to make quick revolutions. All these considerations required the water motor to be suitable for a small quantity of water having a large head, with an efficiency that would not be much influenced within certain limits in the change of the quantity of water. The Girard's turbine with partial openings was settled upon to answer those purposes, and the special design shown in the drawing was made.

The chief dimensions are as follows:—

Head of water	80 feet.
Quantity of water per second	3.2 cub. feet
Diameter of turbine	30 inches.

Number of revolutions .... 240 per minute.
Horse power .... 22.

It was constructed by Katzutaro Otani, Osaka, Japan, in April 1889, and was fitted up at the mine in September of the same year and since then it has been working with complete satisfaction.

This kind of turbine does not exist in any other place in Japan, and its chief advantages are as follows :—

1st.—Its power may be regulated for any quantity of water without materially reducing the efficiency of the motor.

2nd.—Its number of revolutions is comparatively small and thus dispenses with the use of gearing.

3rd.—The wheel being vertical, power is easily trasmitted by belting.

4th.—The moving parts are well balanced.

5th.—Parts are well divided, so that there are no heavy castings inconvenient for transportation.

6th.—Fitting up is easily done.

KARUIZAWA SILVER MINE.

Position :—The Karuizawa mine is situated at Karuizawa, Higashi-kawa village, Onuma-gori, Iwashiro province, Fukushima Prefecture, 14½ miles south-west of the town of Wakamatsu.

General History :—It was discovered and located somewhere between 1563 and 1582 by Hanzaemon of Etchiū and Jiemon of Karuizawa. In the year 1596 to 1615 when this part of the country was held by Kato Yoshiakira, a feudal lord, the mine is said to have been quite prosperous with a monthly produce of 30–40 *kwamme* of silver. A little more than one hundred and twenty years later, or in the year 1736–1741, it was at its lowest ebb of prosperity; the number of families living about the mine were reduced from more than a thousand to one or two. Since then until the Restoration, the vicissitudes it encountered have not been handed down. In the first year of the Restoration (1868), it came under the management of Takachi Kumazo of the Muramatsu clan of Echigo, seven years later under Morita Shinzō of Tosa, and soon after under Oshima Takato of Iwate. Under Oshima's management the yield was two to three *kwamme* a month. In 1878 Oshima entered into a copartnership with Furukawa Ichibei of Tokyo, who, in May 1881, made himself the sole lessee. Then the yield per month was five or six *kwamme* and the expenditures were more than the receipts. In 1885 the discovery of clay ore led Furukawa to improve the former system of drainage and to build a new mill, expecting a monthly produce of one hundred *kwamme*. But this expectation was not realized and the business still remained a losing one. In October 1887, however, fortune rewarded

her persevering seeker, showing him over forty *kwamme* and his work payed. Since then the produce has continually been on the increase.

Geological Formation and Ore Deposit:—The rocks surrounding the ore deposits are tuffs of the Tertiary Period. The deposits are in veins in tuff and quartz porphyry. The chief ore is argentite with which baryta and galena are disseminated. The ores are fibrous and run throughout the country rock like a cobweb.

The deposits are over 2000 feet long and several hundred feet wide, but the portion fit for mining only measures 1500 feet long by 100 feet wide. They course from north nine degrees east to south nine degrees west, and as they run southward incline gradually eastward. After about 1500 feet the course becomes north seventy degrees west to south seventy degrees east. The dip which is thirty to seventy degrees, is first eastward and then gradually turns northward until it becomes due north.

The floor or lower strata has been sought for by laborious prospecting during many years, but it is not yet definitely known.

The above mentioned facts suggest that the irregular deposits are a form of impregnation.

Mining:—The mine was first wrought by the cross-cut method, but it had the following drawbacks:—

1.—It is only possible to mine the richer ores, with the result that the general quality of ores are poorer than with other systems.

2.—Blasting on any extended scale is impossible, which is not favourable for rapid work.

Therefore the mining system was improved, the richer ores were sought for and as large blasts which do not necessitate the use of timbering, were made the rapidity of work was increased nearly five times and the expenditure decreased by six times.

The daily produce is nearly 60,000 *kwamme*, while the number of miners employed is not more than one hundred.

The greater galleries, where ores are extracted, measure over 40 feet in breadth by 30 feet in height and where they communicate above

with below and to the right and to the left, they look like mansions of three or four stories.

Ores :—The raw ores contain on an average 0.01 % of silver. These yield 25 % of dressed ores on hand picking. The dressed ores contain 2.8 to 3 % of silver.

Shafts and Levels :—The ores are all extracted in the upper portions of the mine, an excavation of only twenty feet having been made below the drainage level, for the purpose of prospecting. So there is no shaft truly worth the name and only winzes for dropping ores through and for path-ways.

The total length of levels is 7,432 feet.

Cost of Mining :—

Extraction per 100 *kwamme* of raw ore together with cost of transportation in the pit	15.50 *sen.*
Extraction per 100 *kwamme* of dressed ore	55.80 ,,
Dressing per 100 *kwamme* of dressed ore	24.90 ,,

Position of the Mill :—The stamp-mill, the roasting furnaces, the laboratory, etc. are placed near the dressing house, which stands near the mouth of the lowest adit level.

Metallurgy known prior to the Restoration :—The ancient system of metallurgy is unknown. The processes pursued a few years before and after the Restoration were as follows :—

Ore is first crushed in mortars, then washed in water and treated with bamboo baskets. The finer portion is then washed through cotton cloth, while the rougher is further dressed by means of the round rocking board. That portion which passes through the cloth is made into balls about as large as the fist. These balls are roasted in a hearth 2.8 ft. wide and about the same depth, and afterwards subjected to the processes of cupellation and refining.

Metallurgy introduced after the Restoration:—In 1877, when the claim came to be worked by Oshima Takato, the western method was adopted in dressing ores. Ten wooden stamps run by water power, and a number of jiggers were then introduced.

Two years later, when Furukawa Ichibei became connected with the mine, more wooden stamps were set up, and the general method of working was the same as when Oshima had been the sole owner. No profit was realized. In 1879, when Furukawa became the sole owner, he introduced the Augustin method, but still there was no profit, and about five years later, when the ore production increased considerably, new buildings were erected, and Blake crushers and Chrome rolls introduced, making quite a revolution in the entire system of working. In 1890, twenty five iron stamps were introduced and since then after meeting with several hard turns of fortune, the present prosperity has been attained.

Metallurgical System now Practised:—The ore is crushed by male labourers into pebbles measuring about 3 cubic inches, which are further broken into 1 to 1½ cubic inch pieces by female labourers. These are assorted into rubbish and the picked ore. The latter is again divided into two sorts.—A, the softer portion, not containing much sulphide mixture, and B, the harder portion, containing much sulphide mixture. These two sorts go again into female hands to be further picked. After that the former is sent to the crushers and broken into about ½ cubic inch pieces, then to the first roll to be further crushed, and next to the second roll to be pulverized into a powder to pass through 20 meshes to the inch. This powder goes to the roasting furnace. After ores are crushed, when yet fresh from the mines, they often contain more than 10 % of moisture, greatly interfering with the use of trommels. Fans were, therefore proposed and are used at present. Two Blake crushers, each 8 inches diameter, and two Chrome rolls 28 inches in diameter, and 14 inches wide, are used in treating the A, sort of ore, which is dressed usually at the rate of 11,000 *kwamme* per 24 hours.

The B, sort of ore first goes to the stamp-mill, and is pulverized as in the case with the A, sort, after which it is dried by utilizing a part of the surplus heat of the roasting furnace, and next sent to the roasting furnace. There are 35 iron and 55 wooden stamps, but the water power being unsteady, and the supply of raw ores insufficient, only 3,000 to 5,000 *kwamme* are dressed per 24 hours.

For roasting, reverberatory furnaces each 27.5 ft. long and 10.5 ft. wide, each having three openings or doors are used. Of these furnaces there are twelve, of which only five or six are employed on ordinary days. One charge is ordinarily 120 *kwamme* of ore, and this is transferred every hour to the next chamber. In the last chamber about 3 % of common salt is added after 30–40 minutes and mixed together and roasted well during the additional 20–30 minutes. The charge is then drawn out to the ore trucks and sent to the ore storehouse. In each furnace 2,880 *kwamme* of ore are roasted in 20 hours.

The roasted ores having a great heat are directly, taken to lixiviating tanks and yield a solution of common salt which is of 75° Fah. temperature and about 8° B. but the temperature increases at the beginning sometimes reaching 90°. The solution flows out to the precipitating tanks which are arranged on a lower level. Thus silver and copper are precipitated in tanks each provided with copper plates and grains and iron filings, and the brine from the silver and copper is pumped back by wooden pumps into the reservoir to be reheated and again used.

The lixiviation takes about 18 hours and when the charges have been exhausted of silver they are taken to the washing house, where they are washed with hot water for four or five hours and after that sent to the rubbish heap. The washing water contains more or less silver, therefore after concentration in the reservoir it is reheated as silver solution. An injector is provided in the lower reservoir and the solution is pumped up to the higher one by a pump. There it is warmed by means of steam to the temperature 80° Fah. and again used.

A charge of one tank is 75 *kwamme* of ore. There are 150 lixiviation tanks, 75 silver precipitation, and 38 copper precipitation tanks.

The product is taken out once or twice during one month, and it is pressed to take away the moisture by female workers and subjected to the liquition process by a small blast furnace, and refined with an English cupellation furnace, and cast into iron moulds. The ingot weighs 57 *kwamme* and contains 99½ % of pure silver.

Percentage of Extraction:—What is actually obtained as the result of metallurgical operations is only 60 % of what chemical analysis indicates, and investigations are being made as to how to increase the yield.

Supply of Fuel:—The neighboring forests have all been cut down, and therefore both wood and charcoal have to be brought from places 9 to 15 miles distant. A part of this distance, wood can be made to float down a river, but for over 5 miles the only means for transportation is the use of horses and hand-wagons. Fuel is therefore expensive, wood costing 1.70 *yen* per *tana* ($5 \times 6 \times 2\frac{1}{2}$ ft.), and charcoal, 26 *sen* per 10 *kwamme*, with cost of transportation.

A few years ago, coal was found at several places about 3 miles from the mine, and since then it has been used in such quantities as to amount to 40 % of the fuel consumed. Its quality, however, is indifferent, and its use does not result in any marked economy.

Expenses of Working:—

Dressing	0.45	*yen*	per 100	*kwamme*.
Roasting	0.56	,,	,,	,,
Precipitation	0.20	,,	,,	,,
Refining	0.06	,,	,,	,,
	1.27 *yen*.			

Production Statistics :—

Date.	Silver in *kwamme*.	Average monthly yield.
1882 (the latter half of)	14.750	2.458
1883 (from April to Sep.)......	32.330	5.388
1884................................	94.700	7.850
1885................................	180.370	15.030
1886................................	154.075	12.813
1887................................	356.519	28.043
1888................................	611.140	50.922
1889................................	609.220	50.769
1890................................	821.915	68.493
1891................................	857.460	71.455
At present........................	——	72.000 to 73.000

Use of steam, water, etc. as Power :—For dressing use, two booilers 4.8 ft. in diameter and 9 ft. long, 4 water-wheels 15 ft. in diameter and 3.7 ft. wide, are used, and for precipitation one boiler of the same style as above is employed.

Hitherto, 15 out of the 35 iron stamps employed, were run by steam, and the rest by water power. But lately a Pelton wheel 3 ft. in diameter has been employed and 25 iron stamps have been run by it. This has resulted in a saving of 300 *yen* per month in fuel alone, and to so accelerate the work that the wooden stamps are useless.

Transportation :—As before alluded to, ores are mostly extracted above the drainage level, and consequently the inconvenience of raising ores from below is limited. The greater portion is dropped from above through inclined or straight winzes. The extracted ores are first conveyed in wheel-barrows, but when they reach the tramways, they are taken in wagons of 82-120 *kwamme* capacity.

On the surface "open work" is often resorted to in much the same fashion as in the pits, the additional plant only being the frequent use of wire-rope tramways for short distances.

From the pit-mouth in the upper portion of the mine to the dressing mill, ores are carried on the so-called "earth-sledges," which are 2 ft. wide by 8.5 ft. long, and similar to common sledges in shape, but somewhat stronger. Where the ground slopes considerably, sleepers are laid on the ground, and on them the sledges are run. A single man can thus carry 120-200 *kwamme* at a time. In dry weather water is sprinkled on the sleepers so as to reduce the friction.

Distances to Markets:—A wagon-road runs 14¼ miles to Wakamatzu, 70 miles from Niigata,–half the distance being by wagon road and the other half by water, and 180 miles to Tokyo.

KOSAKA SILVER MINE.

Situation:—The Kosaka Silver Mine is situated at Kosaka village in Kazuno-gori in the north-eastern part of the province of Rikuchiu belonging to Akita-ken in lat. 40° 21′ North and long. 140° 37′ East. It consists of a group of hills rising about three hundred to four hundred feet above a high plain, which is about eight hundred feet above sea level. On the high plain and in the valleys at the foot of the mine, there are about one hundred and fifty buildings, the office, the dressing house, and dwellings for officers, miners, etc.

General History:—In March 1829, Kumagae Tazaemon, a peasant of Kosaka village, discovered lead ores in the northern part of the present claim. How he made the discovery is unknown. He named the place Sugihara mine and worked it for a time.

On August 25th, 1861, a peasant of Kosaka village, Kobayashi Yosaku by name, and Kishi Tōtaro of Hisayoshi village, Tsugaru-gori in Mutsu, found some stones, while exploring for the abandoned Sugihara mine, in a dale named Baramori-sawa about ⅛ of a mile from the place to which they were bound. They broke one of them and found it to be like some metallic ore. Upon their taking a few of them home and smelting them in a ground hearth their surmise proved correct. They indeed yielded a fair proportion of silver. Thereupon they commenced to mine at the place where they found the stones.

The first discoverer was not able to work the ores he found, and so after a short time he abandoned the mine. Kobayashi Yosaku, the second discoverer, was more successful. With the permission of the feudal lord of the place, he built some miner's huts near Baramori-sawa. The ores that he extracted he carried to his home and there

occasionally worked at them. He went on in this way until 1866, when he was obliged to transfer the mine to the Nambu clan, whose head was disposed to carry on the mining industry on an extended scale. Oshima Takatō, a vassal of Lord Nambu and a mining engineer, was appointed to the directorship of the mine. He built a mill, erected smelting and cupelling furnaces after the western style, and had almost completed the arrangements for commencing work, when the Revolutionary War broke out and everything came to a standstill.

In January 1870 the Imperial Government appointed Oshima Takatō, the Nambu engineer, (a high official of the Public Works Department) to the management of this mine. He completed the various works he had formerly started, and put the mine in working condition. In 1873, Mr. C. Netto, a German mining engineer, was engaged and the improvements he introduced in the metallurgical methods greatly augmented the scale of work. In June 1877, the Government discharged Mr. C. Netto and leased the mine to Nambu, the former feudal lord, who, after working it for some three years, though the produce was by no means small owing to Mr. C. Netto's improvements, was obliged to return it to the Government, for wages and prices rose too high. The Government also had hard times with it and was about abandoning it, when in March 1881, owing to the introduction of great improvements it showed an entirely new aspect proving itself one of the most profitable mines in the Empire.

In September, 1884, Messrs. Fujita and Co. of Osaka came into possession. They still hold it and from time to time are introducing such improvements as occur to them.

Gelogical Formation, Ore Deposits, and Ores:—Light blue tuff of the Tertiary Period coursing from the north to the south and dipping thirty to sixty degrees to the east. Through the fissures in the tuff quartz and andesite shoot out. The hills and plain are covered with pumice stone and new volcanic ashes from two to thirty feet in depth.

There is only one large deposit. It is evidently of volcanic origin and lies in tuff near the junction of the tuff and andesite. It runs nearly parallel with the country rock and twenty to one hundred and forty feet wide, though in most places it is only seventy to eighty feet. Its length, so far has been ascertained up to this day by excavation and boring, is over two thousand feet and its bottom has not yet been reached beyond two hundred feet from the top of the outcrop.

The body of the deposit is entirely metallic from the hanging to the foot wall. In the ore volcanic ashes are often seen. Sometimes it is found cemented with lava and looking like hornblende conglomerate. It is often observed making regular strata, as if it were a stratified deposit. A clear line of demarkation is seen between the hanging wall and the deposit, but there is nothing like this between the latter and the foot-wall. As the ore approaches the foot-wall, it becomes poorer and poorer, until all trace of it is lost in the rock. This may be due to a portion of the deposit having entered the foot-wall,—which is rather coarse in texture—at the time of the formation of the ore. The stratified appearance of the ore above referred to is perhaps because a portion of the deposit burst into the strata of the tuff as there is no testimony to the deposit being fully stratified.

The ore in the lower part of the deposit consists mainly of galena, zinc blende, copper pyrites, iron pyrites, and gray copper ore. All these minerals are in small crystals and homogeneously combined make what is called *kuromono* or "black ore." The veinstuff of this ore is chiefly heavy spar with small proportions of gypsum, quartz, etc.

The following is the percentage composition of the better kinds of ore :—

Gold	0.0003
Silver	0.03
Copper	2.96
Lead	8.02

Zinc	12.26
Iron	7.69
Tin	0.50
Bismuth	0.21
Antimony	0.20
Arsenic	0.51
Alumina	5.45
Lime	1.12
Magnesia	0.64
Silica	2.50
Sulphur	22.02
Barium Sulphate	35.17
	99.2803

Of the several minerals that combine to form the black ore, the richest in silver is the gray copper ore, which occurs very rarely. The other minerals are argentiferous in the following order: galena, copper pyrites, zinc blende, iron pyrites. Iron pyrites is richest in gold though poorest in silver.

In the upper 100 ft. of the deposits the ore is greatly decomposed and has the appearance of sandy earth. It is either green, yellow, brown, red, gray, or white in colour, and so is locally termed "earthy ore" *doko*. In the proportions in which it contains silver, the green and yellow sorts rank first, the brown second, the red third, the gray fourth, and the white fifth. The superior sort of it, the composition of which is as follows, contains 0.036 % of silver while the common sort contains on an average only 0.027 %.

Silver	0.036
Copper	0.23
Lead	4.42
Iron	7.41
Zinc	2.44
Alumina	1.85
Silica	27.00

Lime	1.50
Magnesia	0.35
Sulphur	2.66
Barium Sulphate	49.28
	96.176

Mining:—The ore deposit can be mined for the upper 300 feet by means of levels driven into the hills from the neighbouring valleys. The principal object at present is to mine the earthy ore. Therefore no main shaft yet has been sunk, anything of that nature in the mine being the winzes sunk for connecting lower levels with upper ones for the purpose of ventilation. The levels of which No. 1 is driven 150 feet from the top of the outcrop, No. 2, 50 feet lower, No. 3, another 50 feet lower, and No. 4, 70 feet lower from No. 3, are 5 to 6 feet wide and 6 feet high. No. 1, there is only earthy ore. This accumulates in a form something like coal seams in hollows in the containing rock. This is therefore mined by a method somewhat like the usual coal mining process. Near the outcrop the surface earth is removed and the ore is extracted by quarrying. No. 2 and No. 3 have been driven straight forward, the former 1,200 feet, and the latter 1,700 feet. From both of these several branches have been excavated for prospecting and mining work. No. 4 nearly at right angles with the deposit is being driven for the purpose of meeting No. 3 and it is hoped that the object will be attained within a few months.

At present only earthy ore is extracted. After being carried out of the levels it is put through ½ inch trommels or common sieves and the portion that passes through them is sent to the mill. The other portion goes to women or children, who select the richer pieces and break them with hammers. The broken pieces are put on ⅜ inch sieves and the portion that passes through goes to be metallurgically treated together with the portion first selected.

Cost of Mining:—The monthly out-put of ore at present is about 3,000 tons, the mining and prospecting expenses for which are as follows:—

Prospecting by boring	10.00 *yen.*
Removal of the surface earth	90.00 „
Prospecting work in levels	790.00 „
Repairing of levels	390.00 „
Building and repairing rail roads	80.00 „
	1,360.00 *yen.*

This means 45 *sen* per ton of ore. The mining and crushing expenses of the same are 3.17 *yen*, i. e. 1.06 *yen* per ton, as detailed below:—

Mining	2.67 *yen.*
Crushing	50 „
	3.17 *yen.*

This includes the expense of transportation from underground to the drying house.

The black ore is not yet mined. The expenses for mining cannot therefore be stated with any definiteness, but are supposed to be about 2 *yen* per ton.

The Mill:—The mill is located about one mile south of the mine, about 500 feet below No. 1 level and 580 feet above the sea. About ⅓ mile north of the mill and about 100 feet above it, is the drying house, where the ore is dried to expel moisture before it is pulverized. Above it there is the storehouse for ores. Below the drying house there is the crushing mill and above it there is a reservoir about 750 feet long and about 400 feet wide for keeping water to drive crushing machines. There is another reservoir to keep water for running the pumps used in precipitation and the blowing machines at the foundry and the forge. Besides the establishments above named there is a tilery and a workshop so that any common machines and implements can be manufactured here.

Near the mill there are houses for officers and miners, shops, stores, hotels, etc. They number some two hundred and sixty in all.

The number of people engaged in the mine and mill work in this district, is about two thousand.

Metallurgy:—History and Improvements. Before 1868 the ore broken into about 1 inch pieces was roasted, with charcoal in a hearth about 2 feet, in diameter and 1.5 feet deep dug in the ground and lined with a mixture of slag and powdered charcoal. The bellows used were made of wood. No flux was used. The argentiferous lead produced in the hearth was smelted in a shallow hearth made of wood ashes where the lead was oxidized and removed. In this case also charcoal was a part of the charge. On account of a large proportion of zinc contained in the ore, the matte and the slag could not be worked.

The methods introduced by Mr. Oshima in 1870 were about as follows:—

I.—The black ore was broken into about one inch pieces and roasted in heaps.

II.—The roasted ore and the earthy ore were mixed in certain proportions and heated with charcoal, silicious sand, and slag in a blast furnace. The matte produced was put into a special kettle before it solidified, and was mixed with lead smelted in another hearth. The mixture was stirred and the matte stripped off as it formed. The argentiferous lead in the bottom was ladled into moulds.

III.—The matte desilverized as above stated was broken into about 2 inch pieces and roasted in heaps.

IV.—The roasted matte was heated in a ground hearth, together with suitable proportions of litharge and slag; and argentiferous lead regulus and a matte rich in copper was obtained. This matte was again roasted and smelted for crude copper and the matte produced was again worked.

V.—The argentiferous lead regulus was treated by the English cupelling process.

Mr. Oshima's system was far better than the old one and it was

by him that the smelting and cupelling furnaces were first introduced into this country.

When in 1873, Mr. C. Netto was appointed the Chief Engineer he introduced the newest inventions of his time and achieved remarkable improvements. These methods were:

I.—Roasting the black ore in heaps.

II.—Smelting the roasted and earthy ores in a Mansfeld furnace and making the matte produced, into small pieces by putting it into cold water.

III.—Pulverizing the matte treated as above in a mortar.

IV.—Roasting the pulverized matte in a double reverberatory furnace and converting the silver into silver sulphate.

V.—Desilverizing the silver sulphate by the Ziervogel process.

VI.—Extracting copper from the slag by the Hunt and Douglas process.

VII.—Refining the silver precipitate by cupellation and making the refined metal into bullion by casting.

VIII.—Smelting the copper precipitate in a ground hearth and casting the purified metal.

By these methods thrice as much as under the Oshima system, (i. e. 75% of silver and about 45% of copper), was obtained. Though the scale of work became larger through Mr. C. Netto's methods, there came up a difficulty of no inconsiderable nature, i. e. the rising of wages and of prices in general, especially that of fuel, the neighboring forests nearly dissappearing, the smelting processes had been practiced so long and consumed so much. It became painfully evident to the managers that Mr. C. Netto's system could not be long continued. They therefore turned their attention to other processes and made manifold experiments to reduce the consumption of fuel, which eventually ended in the adoption of the chlorination process and Augustine's method of desilverization in the treatment of the earthy ore, dispensing with the smelting process formerly resorted to. The newly adopted processes were first practiced in 1881 and greatly changed the system of work.

This system, a little inproved, is now as follows :—

I.—That portion of the earthy ore which has passed through ¼ inch sieves is dried in a furnace, 4 feet in diameter and 30 feet high. This furnace dries 100 tons of ore and consumes 400 cubic feet of wood in 24 hours.

II.—The dried ore is pulverized in two Cornish rolls, each 18 inches in diameter so fine as to pass through ¼ inch sieves. This work is done in a day of ten hours driving the rolls by means of a water-wheel 20 feet in diameter and 10 feet wide, the force required being not more than ten horse power.

III.—With the powdered ore 4 % common salt is mixed and the mixture is roasted in a long, flat reverberatory furnace 12 feet wide and 27 feet long and divided into three compartments on each side of which is a hole. The fire-place 2 feet wide and 9 feet deep is so made as to receive fuel both in front and at the back. The ore at the rate of 1,700 pounds at a time is put into the compartment of the furnace lying farthest from the fire-place and transferred into the next compartment every twenty minutes, so that it takes one hour to roast the above quantity of ore. Two such furnaces suffice for making 100 tons of roasted ore per day. The quantity of wood consumed in a furnace of this description is about 700 cubic feet.

IV.—The roasted ore after it has been allowed to cool is subjected to the Augustine process. Twenty one tanks, each 5 feet in the shorter diameter, 7 feet long, and 2.5 feet deep, are used for dissolving the roasted ore. Each tank receives three tons of the roasted ore and the whole quantity is dissolved in about twelve hours. The solution of common salt used contains about 20 % of salt and has a temperature of about 70 degrees. These tanks are rather too small, but the dimension of the mill do not admit replacing them with larger ones. There are four basins

in which precipitation of silver takes place, arranged one above another. They are made of brick and lined with cement. The solution from the tanks allows the impurities it contains to fall to the bottom of No. 1 basin. In No. 2 basin the silver is precipitated by means of copper plates and grains. In No. 3 basin the same reaction as in No. 2 continues. In No. 4 or the last basin, copper is separated by iron filings; from this basin the solution flows into the sump, has a little common salt added, and is raised by means of a wooden pump into a tank placed in the highest part of the establishment and specially provided for keeping this refuse solution, which after being warmed by steam, is again made to flow into the tanks.

V.—The silver precipitate is made into a round mass in a screw-press and dried in a vessel in shape like a still. It is afterward treated in an English cupelling furnace. It contains from 15 to 70 % of silver.

VI.—After cupellation it is fused in a graphite crucible and made into bullion by casting the molten metal in iron moulds. This bullion contains about 98.5 % of silver.

VII.—The treatment of the copper precipitate:—The copper precipitate contains some 60 % of copper. One half of the whole produce of this material is cast into copper ingots and sent to market; the other half is purified and made into copper plates and grains for use in the process of precipitation.

It is the earthy ore alone that can be treated as above described and therefore the black ore has been laid aside unworked since the introduction of the chlorination process. But as the former ore does not exist in unlimited quantities, this mine must be abandoned when it has been used up, unless some good method of treating the latter ore be invented. This being the case, numerous experiments have been tried to hit upon an economical method of treating the black ore, but no success has hitherto been attained. The following method

which is perhaps the best of all the methods ever invented, though not satisfactory, is now being practiced upon a few tons per month by way of experiment:—

I.—The ore is crushed into pieces one inch or less in size.

II.—Roasting the ore twice in a stove or kiln. The kiln used is 6 feet wide, 10 feet long, and in height 3.5 feet in front and 2.5 feet at the back. Its bottom rises gradually from front to rear. From the two air-holes in the lower part of the front wall there runs an air-tube nearly to the back wall. In the cover of this tube there are holes at several points in order to let every part of the ore-heap have its due proportion of air. The ore at the rate of 8 tons at a time is heaped upon about 45 cubic feet of wood placed in the bottom of the kiln. The number of days required to roast the above-mentioned quantity of ore is seven to ten.

III.—The roasted ore is treated in Chrome rolls and made into a powder so fine as to pass sieves with twenty holes to the inch.

IV.—The powdered ore with 4 % of common salt added is roasted in a reverberatory furnace. The furnace used is of the same type as that used in roasting the earthy ore. The quantity of ore per chage is 1,700 lbs. and the number of hours required is six.

V.—The roasted ore is subjected to the Augustine process in the same manner as in the case of the earthy ore and the greater part of the silver and copper are extracted.

VI.—The residue from the above treatment is subjected to the Kiss process and the silver and gold in the residue are extracted.

VII.—The treatment of the silver precipitate.

VIII.—The treatment of the copper precipitate.

VII and VIII are the same as in the case of earthy ore.

IX.—The treatment of the sulphides. The sulphides, after being

pressed, made into round masses, and dried, are roasted in a muffle and smelted in a small blast furnace. The argentiferous lead regulus produced is cupelled and cast into bullion, which is sent to market.

Statistics of Production:—At present about 3,000 tons of the earthy ore are worked giving the following out-put:—

Bullion (containing 98.5 % of silver)	18,000 ounces.
Black Copper (containing about 93 % of copper)	16,000 pounds.

Percentage of Extraction:—The percentage of extraction in 1891 was 78.59 % of the silver and 70.43 % of the copper in the original ore.

Cost of Working:—The cost of working three thousand tons of the earthy ore is about 7.141 *yen* as shown below:—

Drying and dressing	0.732 *yen*
Chlorination	3.700 „
Dissolution and precipitation.......................	1.920 „
Working the copper precipitate and making black copper	0.501 „
Working the silver precipitate	0.288 „
	7.141 *yen.*

This means about 2.23 *yen* per ton.

The black ore is not yet fully worked at present, but if done so, the working of 70 tons of it per day would take 352.66 *yen*, i. e. 5.04 *yen* per ton as shown below:—

Roasting	41.60 *yen.*
Dressing	34.74 „
Chlorination	139.51 „
Dissolution and precipitation	105.51 „
Refining	31.30 „
	352,66 *yen.*

Wages and Prices:—The wages paid in this mine are much lower than those paid in America, but are among the highest paid in the different mines of this country. They are as follows:—

Kinds of work.	Number of hours.	Wages in *sen*.
Mining and prospecting	8	18 to 38
Roasting	12	20 „ 40
Precipitation	12	18 „ 38
Forging	10	20 „ 40
Carpenters work	10	15 „ 42

Fuel and other materials:—Coal is not found in this district and, since it is not either easy or economical to take it from Hokkaidō or Kiushiu, either by land or water, only wood and charcoal are used for fuel. Fuel is getting scarce in the neighborhood and even at present is brought from the mountains 5 to 15 miles away. Lime and sulphur are found in the district. Common salt is brought from Chiugoku or the Inland sea and iron filings are brought from Tokyo.

The prices of these things are about as follows:—

Wood	2.00 *yen*.	per	100	cub. ft.
Charcoal	7.70	„	„	ton.
Common salt	17.40	„	„	„
Sulphur	15.00	„	„	„
Lime	12.00	„	„	„

Transportation:—Ores are transported by means of wagons, each ½ tons capacity and drawn by men on railroads, which are built both underground and on the surface, and where it is impossible to construct a railroad, ores are carried on men's shoulders.

The wood is chiefly taken to the mine by letting it flow down the streams. Where that is impossible, it is brought in wagons drawn by horses or on sledges in the snowy season. Charcoal is chiefly brought on horseback.

Power:—As there is no shaft yet sunk, there is no need for a winding engine. Drainage and ventilation need no engine; they can safely be left to nature. Thus neither steam nor water power is needed in the mining work.

In the mill work, water sufficient to produce 20 horse-power is used:—

10 horse-power	For driving a water-wheel for 10 hours every day to run two Cornish rolls used to pulverize the ores.
10 horse-power	For driving a similar water-wheel for running five wooden pumps used to raise the common salt solution, the blowing machines used in the mill and the forge, and the mortar mill and brick making machines occasionally used.

For keeping water necessary for producing the power needed as above stated there are two reservoirs one placed above the other, so that the same water may be used on both water-wheels.

There are two steam-boilers provided and alternately used for warming the common salt solution used in the precipitation process,

Markets:—The silver bullion is taken to Morioka, 62 miles south-east of the mine, either in horse-wagons or on horseback and thence sent to the Osaka Mint, by railroad, to be cast into coins.

The copper is sent to port Nojiro in junks on the Yoneshiro river and thence to Osaka in steamers.

TOWADA MINE.

Position:—The Towada mine is on the west shore of Lake Towada in the north corner of Katsuno-gori, in the province of Rikuchiu, Akita-ken. Since Lake Towada is completely surrounded by lofty mountains, no market can be reached from this mine without going over several miles of precipitous passes.

There is another mine called Namari-yama on the shore of Lake Towada situated four miles south from the Towada mine.

General History:—The Towada mine was discovered in September 1718 and the Namari-yama mine in September 1661; the former from April 1720, and the latter from the date of its discovery, were worked by Shirane Denkichi. Since then till 1845 they underwent frequent changes of ownership when Marquis Nambu took them into his hands; and held them till April 1873, when he transferred them to the Government. The Government after working them for nearly four years, sold them to Yoshida Tokichi.

In September 1878 Marquis Nambu again purchased them from Yoshida and again transferred them to the government after working them for nearly two years. The government worked them till September 1884, when Messrs. Fujita & Co. of Osaka bought them, and they still owned and worked by that company.

Geological Formation and Ore Deposits:—This mine has only one principal vein which is composed of clay and gypsum. Both the hanging and the foot walls are of blue tuff belonging to the Tertiary Period, along the hanging wall there is a band of clay 20 feet wide while on the foot wall there is a band of gypsum also 20 feet wide. The vein courses nearly from south to north and dips from 20 to 65 degrees to the east,

The ores in the form of masses or of layers are found in clay. The principal ores are argentite and copper pyrites containing a little gold.

The veins of the Namari-yama mine are regular. They strike from south-west to north-east and dip 70° to 85° to south-east. They vary from one to three feet in width. The country rock is the same as the Towada mine only a little harder. The principal ores are galena, copper pyrites, and zinc blende, each of which contains more or less silver.

The Namari-yama mine is now unworked, therefore what is said below refers to the Towada mine.

Quality of Ores:—No great variations are seen in the grade of ores. Most of them are found in large masses of invariable composition.

1. Silver Ore.—There are two kinds of silver ores; viz.:—

a. "Black ore."
b. "Red ore."

a. "Black ore" so called from its black color contains:—

Silver	0.06 %
Lead	15.00 ,,
Copper	4.00 ,,

b. "Red ore" so called from its reddish color contains:—

Silver	0.07 %
Lead	2.00 ,,
Copper	0.70 ,,

2. Copper Ore.—The copper ore contains:—

Copper	10.00 %
Silver	0.02 ,,

Each of these ores contains a little gold.

Levels:—From the point where the vein crops out to the lowest or drainage level, it measures about 350 feet. The total length of the levels is nearly 2250 feet,

Cost of Mining:—The cost of mining 100 *kwamme* of ore is from 0.80 *yen* to 1.00 *yen*, and the work of prospecting is calculated to require about as much per 100 *kwamme* of ore. Hence the expenses of prospecting and mining put together amount from 1.60 *yen* to 2.00 *yen* per 100 *kwamme* of ore.

Metallurgical work:—The metallurgical work is situated on a plain on the west shore of Lake Towada about one mile from the mine. This distance is by no means flat, and hardly allows the free passage of wagons.

Before the Restoration all the metallurgical processes were carried on by purely Japanese methods.

Metallurgy introduced after the Restoration:—The old Japanese methods were pursued until 1880 without the introduction of any foreign process. Since then gradual but steady improvements have been made and the following are the methods now practiced.

The ores extracted from the mine are put into straw bags each 120 to 150 *kwamme* capacity, which are carried on sleds in the winter and on wagons in the other seasons.

They are dropped through wooden troughs to the place where they are roasted in heaps.

In order to remove zinc sulphide and also to convert it into the sulphate form, the ores are thrice roasted, after which they are passed through copper sieves 15 millimetre mesh, and sorted into two portions:—

a. that which passes through the sieve.

b. that which does not pass through the sieve.

The portion *a* is sent to the washing department, and the portion *b* is once more roasted and sifted as before, sending away the powdery portion to be washed, while the portion left on the sieve is crushed with hammers by female laborers. This latter portion, after being thus crushed, is again roasted in 1,000 to 3,000 *kwamme* at one charge. It takes from seven to ten days for one operation.

The roasted ores are washed in order to remove the soluble sulphate of zinc abundantly produced during the process of roasting.

The washed ores are smelted in a Japanese hearth furnace together with litharge and flux. The litharge is reduced into lead, and absorbing the gold and silver in the ore, sinks to the bottom. A portion of the copper compounds in the ores is also reduced and absorbed by the lead, which the other portion combining with sulphur forms the matte which floats upon the lead in the bottom. The flux takes up the various impurities and forms the slag which from time to time flows out.

The lead in the bottom contains, as may be inferred from what has been said above, gold, silver, and copper, and is called "raw lead" This is subjected to the process of cupellation. After roasting it twice or thrice this matte is worked for copper. The slag is roasted and afterward used as flux.

The raw lead contains copper and other substances and to remove them it is smelted by means of a gentle charcoal fire before subjecting it to cupellation. The refined lead is subjected to cupellation according to English practice. The lead oxidizes into litharge and the silver together with the gold is left in the bottom of the cupels. This auriferous silver is smelted in crucibles, cast into ingots, and sold.

The matte produced in the process before described contains 32 or 33 % of copper and about 0.12 % of silver. This after roasting two or three times is worked for copper in the usual Japanese method. The result of this working is:—

a. Black copper containing gold and silver.

b. Matte.

c. Slag.

The black copper *a* is once more smelted, ladled into moulds, and sold without extracting the precious metals it contains. The matte *b* is again roasted twice or thrice and then worked as before.

The residue removed from the raw lead smelting contains much copper and lead, which are separated from each other by a process

called *Namban shibori* or liquation process. During the course of this process the precious metals are mostly absorbed by the lead. The auro-argentiferous lead thus obtained is subjected to cupellation, and the copper which is nearly of the same chemical nature as the auro-argentiferous black copper before mentioned, is smelted, moulded and sold without further working for the noble metals.

Improvement in Metallurgy:—For two years from 1886 to 1888 the Kiss precipitation process was experimented upon by way of improvement in the metallurgical work, but owing to the change in the nature of ores since that time, this otherwise promising process yielded no good result and has therefore been abandoned.

Percentage of Extraction:—About 70 % of the gold and silver contained in the original ore and about as much of the copper including that contained in the auro-argentiferous crude copper is extracted. If the gold and silver in the crude copper are taken into account, the percentage of the precious metals extracted from the original ore is about 80 %.

The expenses of Smelting:—The cost of smelting is 3.50 to 4.00 *yen* per 100 *kwamme* of ore.

Production statistics:—The production statistics from September 1884 when Messrs. Fujita & Co. commenced the working of this mine to December 1891 are as follows:—

Pure Gold	18,242	*kwamme.*
Pure Silver	1,722,035	,,
Refined Copper	4,226,300	lbs.
Ingot Copper	567,212,400	,,

The monthly production at present is:—

1.	Gold and silver in mixture	22,500	*kwamme.*
2.	Auro-argentiferous copper	7,500,000	,,

The quantity of gold in (1) is about 7 % of silver and the percentage composition of (2) is as follows:—

Gold	0.032
Silver	0.280
Copper	75.400
Lead	22.000

Use of Water Power:—One overshot water wheel of 7 horse power is used to drive a Roots' blower which supplies the various hearths and furnaces with compressed air.

Supply of Fuel:—Lake Towada is completely surrounded by dense forests and but for this it is likely that this mine would severely feel the want of fuel for many years to come. The cost of it however, threatens to become higher, as the trees growing near the shores have nearly all been felled, and the supply of wood has to be sought for farther from the water side, upon the mountains.

Transportation:—The ores and rubbish produced from the old level, as the result of the prospecting, and the mining work, is put into trays locally termed *ebu* each 5 to 25 *kwamme* in capacity, which are taken outside on men's shoulders. Those from the new levels are put on four wheeled tubs each about 15° *kwamme* capacity, and conveyed on railways to the dressing house or to the place where rubbish is thrown. From the dressing house to the smelting works they are transported as already stated.

To carry them from one department of the smelting works to another, a certain quantity is put into a large box and this box is carried on a pole on two men's shoulders. But where they have to be transported any great distance, 4 wheeled tubs are used.

Distances to Markets:—The nearest towns are Kemanai, Kuroishi, both about 20 miles from the mine, and those a little farther are Sannohe on the Tokyo–Aomori railway line and Gonohe about 35 miles from the mine.

OMORI SILVER MINE.

Situation:—The Omori mine is situated partly at the village of Omori and partly at Oguni in Jima-gori Iwami Province, Shimane Prefecture, 55 miles to the west of Matsue and 60 miles to the north of Hiroshima.

General History:—This mine was discovered some 580 years ago. At that time, it was first worked by Ouchi Hiroyuki, a feudal lord of that district; but it seems to have ceased working from the year 1334 to 1525,—the proper method of mining not being understood. At the time of Ouchi Yoshioki, 1525, it was reopened by Kamiya Jutei and Mishima Seiemon; all the ores were consigned to Hakata and there smelted, but five years later Jutei accompanied one Sotan Keiju from Hakata for the purpose of introducing silver smelting, who built a furnace at the mine; this was the first silver smelting practiced in this district. It was so productive that in a short time the annual tribute of silver amounted to 1100 plates. From the year 1590 it was under the direct management of the Tokugawa Government. In 1601 Okubo Iwami-no-kami with Harada Hioye of Bitchiu, who understood mining as manager, opened Kamaya-mabu adit level. In a short time, the mine was so productive that the tribute was 3600 *kwamme* of silver per year. The most productive period was from 1600 to 1640, but after that the output for the following reasons gradually failed. All the upper parts of veins were entirely worked out, having worked the faces too far, requiring repairs of many long levels, Much more water came in and the ventilation etc., became worse. In 1872 all the mines were nearly destroyed by a strong earthquake. In 1873 Adachi Soyemon of Matsue got the claim from the Government, and began mining, but being short of capital he was obliged to stop

after working a short time. In September 1885 all the mines were transferred to Messrs. Fujita & Co. of Osaka. By long dead work extending over five years they enlarged the scale of working. It produces at present some 50 *kwamme* of alloy of gold and silver and 20,000 *kin* of copper per month.

Geological Formation and Ore Deposits:—The rocks at this mine are andesite tuff and sandstone, belonging to the Tertiary Period. Ore deposits are found crossing through these effusive and stratified rocks. There are many fissure veins which contain auro-argentiferous copper pyrites and argentiferous galena, associated with siderite, zinc-blende, iron pyrites and quartz. Native silver and argentite are found impregnated in the andesite which seems like conglomerate; it is called locally *Fukuishi.*

Quality of Ore:—Analysis gives the following results:—

Gold	0.000,378 %
Silver	0.054,000 „
Copper	3.460,000 „

Shafts and Levels:—There are nine shafts, seven of them each 100 feet and two each 70 feet deep. The longest level is 7000 feet and many levels are about 3000 feet long.

Cost of Mining:—The expense of mining is 6.50 *yen* per 100 *kwamme* of ore.

Metallurgy:—The smelting works are situated at Aikodani. The metallurgy practiced before and after the Restoration for getting silver bullion and refined copper was as follows:—

1. Ore dressing by hand picking.
2. Roasting by common kiln.
3. *Do-buki*, Copper smelting according to *Yamashita-buki.*
4. *Awase-buki*, Making alloy of copper and lead.
5. *Nanban-buki*, Liquation.
6. *Hai-buki*, Cupellation.

Improvement in Metallurgy:—For dressing ores besides hand picking, dressing machinery was introduced; for roasting, an American Stall roasting furnace; for smelting, a Pilz blast furnace and an English cupelling furnace.

For the metallurgy of silver ore, it is intended to use Russell's wet process.

Production:—The average product for one month is 100,000 *kwamme* of raw ore; it loses 50 % of its weight after dressing.

Percentage of Extraction:—Both silver and copper extracted by smelting is 80 %.

Cost of Smelting:—The expense of smelting is 2.50 *yen* per 100 *kwamme* of dressed ore.

Fuel:—Charcoal and fire-wood are easily obtained from the forests in the neighbourhood of the mine, and coke used for smelting is transported by junks from Wakamatsu in Chikuzen.

Steam and Water as Power:—

1–Pelton water wheel 1½ ft. dia. used underground.
1–35 H.P. Boiler used on the surface.
1–19 ,, ,, ,, ,, ,, ,,
2–Over shot water wheels used on the surface.

Transportation:—The transportation both in and out of the mine is on steel rails with wooden tubs of ½ ton capacity.

Market:—The manufactured metals are sent to Osaka (distant 355 nautical miles) by steamer. The distance by land is 266 miles.

OMAKI SILVER MINE.

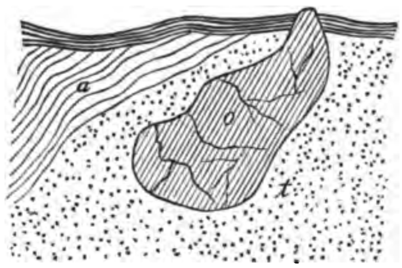
Situation:—The Omaki mine is situated at Nishidate-mura in Kita-Akita-gori, Ugo Province, Akita Prefecture; 77 miles from the town of Akita, and 3 miles from Ogita.

General History:—There is no authentic record telling us about the discovery of the mine, but it is said that, lead was worked about 150 years ago, after which copper ore was discovered; for some time copper and lead were produced, but the workings were stopped from the trouble caused between lessees. In 1885 one Takahashi Jisaburo found an old pit and after some exploration he found rich silver deposits. Araya Keikichi and Ishii Chōbei joined him and they got the claim from the Government. In March 1889 the mine was transferred to Masuda Taka, the head manager of the Mitsui Production Co., who is the present owner.

Geological Formation and Ore Deposits:—The rocks at the mine are chiefly andesites and tuffs belonging to the Tertiary. Tuffy shale and porphyrite crop out in some parts of the mine. The ore deposits are in the form of irregular massive pockets. There are two large workable pockets besides many small ones which are unworkable. One of the large deposits measures, 130 feet from north to south, 90 feet from east to west, and 70 feet from the roof to the floor. The roof is covered with jasper and both the jasper and the deposit are contained in soap-stone. The ore is red oxide silver. Its chief associate is barite containing more or less copper and iron. The roof jasper is impregnated with silver, sometimes containing 0.01 % of silver. At the distance of 720 feet south-east of the former deposit there is another large one. A small part of it crops out on the surface. Its size is 150 feet from north to south, 45

feet from east to west and 150 feet from the roof to the floor. The containing rock, being different from the former, is brown tuff which also contains some minerals. The ore is argentite containing many impurities such as copper pyrites, iron pyrites, barite, zinc blende, and gypsum; small veins of soap-stone are found across the whole deposit.

j—jasper.
o—ore.
s—soap-stone



a—andesite.
o—ore.
t—tuff

Quality of Ore:—Red oxide silver ore; the quality of this ore varies from 0.80-0.05 % of silver, on an average 0.20 %;

Sulphide ore; it is 0.50 % when best, on an average 0.02–0.08%.

The following is the analysis of ores:—

Substances.	Red oxide silver ore.	Sulphide ore.
Slag	1.26 %	0.18 %
Sulphur	trace	8.00
Bariam	95.69	68.18
Lime	1 08	2.52
Gold	trace	trace
Silver	0.26	0.12
Copper	0.08	0.37
Iron	2.01	3.26
Lead	0	15.08
Zinc	trace	3.93

Cost of Mining:—The cost of mining is 44 *sen* per 100 *kwamme* of ore.

Metallurgy:—The site of the mill is at Ohirayama close to the mine. Although the ancient metallurgical processes are unknown, it is supposed that ore which contained the most galena was smelted, and that no oxide ore was worked, because it was thrown away with attle. In the valley we can see a great amount of tailings and slags indicating ancient working; the slag contains sometimes more than 0.07 % of silver. At present the silver is extracted by the Augustine process. The following is the process pursued:—the ore is first crushed to the size of one inch with hand hammers and then subjected to calcination. The finer portion of ore is washed with water and after concentration it is calcined.

Calcination:—Ore is calcined in a heap, and it requires a week to complete. Then it is transferred to a flat calcining furnace (4 feet in height, 8 feet long and 5 feet wide) and calcined again. It requires another week for further oxidization and to render it more brittle.

Stamping:—The calcined ore is pulverized (to pass through $\frac{1}{24}$ inch mesh) by iron stamps weighing 50 *kwamme* each. There are 4 batteries (each set having 5 stamps, making 20 in all). One stamp pulverizes 1,200–2,000 *kwamme* of ore per 24 hours.

Roasting:—There are two reverberatory furnaces which have six holes. They vary in size, the ordinary charge being 200 *kwamme* of ore in one and 150 *kwamme* in another.

The pulverized ore is then roasted strongly by a wood fire, and as soon as it becomes red hot, it is mixed with from 3 to 4 % of common salt to form chloride of silver which is soluble in hot brine.

This operation is completed in 2 or 3 hours for one charge, in 24 hours 16–25 charges are worked. It requires strong heat for conversion into chloride owing to the numerous impurities contained in the ore. The loss is 5–6 *momme* of silver per 10 *kwamme* of ore.

Lixiviation and Precipitation:—The roasted ores, after being allowed to cool, are taken to lixiviating tubs, and treated with a solu-

tion of common salt, which is 80° C. temperature and 1130° B. The solution now falling successively into the series of tubs charged with copper plates and grains, the silver in solution is precipitated on the copper plates and grains prepared in the lower tubs. The brine, thus freed from silver is pumped back again into the reservoir to be reheated and again used.

The silver precipitate is pressed in a screw press and after drying it is treated in an English cupelling furnace. It contains from 50 to 60 % of silver.

After being cupelled, it is fused in a graphite crucible and made into ingots weighing 4 *kwamme* each. The casting is in iron moulds.

This bullion contains about 99,25 % of pure silver.

Improvements in Metallurgy:—Bone ash used in cupelling furnaces being very dear, common cement is substituted for it, there is no change in the result of desilverizing; the following table shows the difference of expense:—

Material.	Cost of material in *yen*.	Cost of building in *yen*.	Total *yen*.	Times used.
Bone Ash ...	18.875	1.457	20.332	2—3
Cement	4.810	.323	5.133	4—5
Difference ...	14.065	1.134	15.199	2—3

Percentage of Extraction:—

Average from January to June, 1891 .... 76.65 %
,, ,, June to December, 1891 ...... 74.12 ,,
,, ,, January to June, 1892 .... 72.70 ,,

The Augustine process is fitted for desilverizing from the red oxide silver ore, which contains less galena, zinc-blende and other impurities. In this case more than 80 % is extracted, but it is not fit for the sulphide ore which contains more impurities; perhaps Russell's process may be suitable for this kind of ore. It is very hard and expensive to change the process, therefore calcination was resorted to

in order to expel more sulphur and cause better oxidization. Therefore after roasting twice, it is subjected to the Augustine process as above described. It takes 30 hours at least to extract more than 80 % of silver, but because it is necessary to complete it in 10–18 hours from the lack of tubes only 73–74 % of silver is at present extracted, the rest being left in residue.

Cost of Milling:—The milling costs 2.207 *yen* per 100 *kwamme* of raw ore, office expenses and officer's wages not being included.

Production Statistics:—The production statistics of silver in the last three years are as follows:—

1890	674.994 *kwamme.*
1891	691.332 ,,
1892 (from January to June).........	305.398 ,,

Fuel:—The average consumption of fire-wood and charcoal during one year is as follows:—Fire-wood 2,175 *tana* (one *tana* being 5 × 20 × 2,4 feet). Charcoal 41,746.800 *kwamme.*

Steam Power:—

1–20	H.P.	Boiler	for working stamps.
1–15	,,	Engine	
1–15	,,	Boiler	for heating brine and running pump.
1–10	,,	Engine	

Transportation:—The transportation in and out of the mine is with tubs on rails run by man power. The shaft is provided with a hand-winch and horse-whim. The mine is situated closely to the Yoneshiro-gawa, a navigable river. Traffic arrangements are convenient, it being 36 miles to Noshiro harbour, and 65 miles to Aomori which connects with the Tokyo line of railroad.

TSUBAKI SILVER MINE.

Situation:—The Tsubaki Mine is situated on the sea shore, on the highway between Akita and Aomori in Hachimori-mura, Yamamoto-gōri, Ugo Province, Akita Prefecture, 80 miles north of Akita and 480 miles from Tokyo. There is a plateau called Tsubaki-dai which is 70 feet above the sea level. The mill is at the mine.

General History:—This mine is quite a new one discovered in August 1889, by one Yatabe Motomasa, who took back some samples of ore and found them to be very rich in silver. By analysis he found that they contained 4.5–0.5 % of silver. Nui Kiuyemon and he began working the mine immediately after the discovery.

Geological Formation and Ore Deposits:—The rocks at this mine are andesites and brown tuffs of Tertiary age. The plateau is formed of tuff in which chloride silver ores are found in the form of stock-work. On the east side, tuff containing iron pyrites crops out, and it is bounded on the west by andesite which crops out on the sea shore. Between these there is a line of tuffy shale, which is an ore bed. It courses from north to south dipping eastwards at an angle of 30°–70°. On the north this shale has many fissures filled with ore. From east to west it is 600 feet wide. At present the workings are about 1,800 feet long and 150 feet deep. The foot wall has not yet been reached. On the southern side a fault runs from east to west dipping southwards 30°. The upper stratum, beyond the fault, has the same strike and dip as the fault. The quality of ore found in the upper part of the stratum is the same as that in the impregnation, but its formation is unequal. On the north the ores are found in many large fissures in tuffy shale while on the south they occur in beds of regular stratified shale which at intervals of 10

feet contains three seams of clay. The thickness of these clay seams are from one to five feet. They contain rich silver ore in their roofs and floors. The black clayish ore is so soft that it is dug out by picks, while the brown stony ore is so hard that it can not be mined without the aid of gunpowder or dynamite. In places, much water gushes out.

The ore consists chiefly of barite associated with galena, argentite, zinc-blende, iron pyrites, and arsenical iron pyrites.

The analysis of the ore is as follows:—

Substances.	No. 1.	No. 2.	No. 3.
Silver	0.07	1.60	1.54
Copper	—	4.80	1.29
Lead	7.30	10.00	3.10
Zinc-blende	3.60	12.00	6.54
Iron	3.30	7.56	5.20
Sulphur	12.50	15.00	11.92
Barite	70.20	38.46	16.44
Silica	—	17.74	43.26
Alum	2.30	—	23.00

Mining:—The mine is not higher than sea level. The present lowest workings are 150 feet below sea level. The ventilation is left to nature. Water underground is pumped up by two 5 inch special pumps. The usual dimensions of the adit level is 4×6 feet and that of the main level 6×7 feet. Rails and tubs are employed. The ores and attle are wound up an incline by a hand-winch at the mouth of the pit. They are then transferred to other tubs and sent to the dressing house, where they are sorted and the larger portion is crushed by hand-hammers to the size of a fist. After picking out rocks a small part is washed by water or concentrated and sent to the drying furnace.

The monthly production of ore amounts to 70,000 *kwamme*.

Cost of Mining:—It costs 2.28 *yen* per 100 *kwamme* of ore. Percentage of silver being 10 *momme* per 1,000 *kwamme*.

Metallurgy:—The metallurgy practiced in this mine is just the same as that of the Kosaka Mine. The main points are as follows:—

1. Ore Drying.
2. Stamping.
3. Roasting.
4. Cooling.
5. Lixiviation.
6. Precipitation.
7. Cupellation.

To expel the moisture the ore is dried before pulverizing. This is done in a drying furnace which is built of bricks on an incline of 32°. At the lower part of this a wood fire is prepared. It consumes 196 cubic feet of fire-wood during 24 hours.

There are five iron stamps, each of them weighing 500 lbs. The dried ore is pulverized to pass through $\frac{1}{18}$ inch mesh and 2,500 *kwamme* of ore are treated in 24 hours. One turbine is employed for running the stamps.

The pulverized ore is next roasted for eight hours for oxidizing. It is then mixed with 5 % of common salt and roasted an additional hour for chlorination, in a long flat reverberatory furnace, 11 feet wide, 40 feet long, and divided into six compartments on each side of which is a hole. Each compartment requires one and a half hours roasting and all is completed in nine hours.

The fire-wood required for roasting during 24 hours amounts to 280 cubic feet.

The roasted ore is allowed to cool for a few hours, after which water is sprinkled on it and it is then sent to the lixiviation tank to subject it to the Augustine process. The operation is the same as that described under the Kosaka and other mines. The precipitate contains about 80 % of silver. The precipitate of copper containing

some lead is subjected to the Japanese smelting process, thus the two metals are separated.

The copper is made into plates and grains, which are used for the precipitation process, and the lead containing a small portion of silver, is subjected to cupellation.

Percentage of Extraction :—The percentage of extraction is 70–80 %.

Cost of Milling :—It costs 1.58 *yen* per 100 *kwamme* of ore.

Production :—On an average 50 *kwamme* of silver are produced per month.

The refined silver has a purity of 995 % of the pure metal in 1,000 parts.

The silver is sent to Tokyo and transferred to the Mint at Osaka.

KAMIOKA SILVER AND COPPER MINE.

Situation:—The Kamioka Mine is situated partly in the town of Funatsu and partly in Asofu village in Yoshiki-gori, Hida province, Gifu Prefecture.

General History:—The discovery of this mine seems to have taken place in very ancient times, as it is often mentioned in very early writings. The exact date, is however, irrevocably lost. The earliest ascertained fact is this; a chief vassal of Kanamori Izumo-no-kami, the head of the Ono clan of Yechizen, Uchida Hikojirō by name, discovered some veins exposed in that part of the present claim, which is locally termed Mayebira and Zuridani, somewhere between 1573 and 1591. A short time later the mining was commenced by Lord Kanamori Morishige. His successors continued it till somewhere between 1684 and 1687, when it had to be stopped in consequence of the noble house having been ordered to govern in some other part of the country.

The mine was under the direct management of the Tokugawa Government from 1817 to 1820.

In 1836 one Shimada Chiubei from Tokyo resumed the work abandoned by the Government. He gave it up after seven years working. Since then till August 1887, when the mine was leased to Mr. Mitsui Chōgorō, it was left to the irregular working of local adventurers.

What the produce was in ancient times is not known, but the present production, of 1800 *kwamme* of silver per year, is perhaps the greatest ever obtained, for it is known that 600 *kwamme* per year was before and after 1877, spoken of as being very great,

The whole claim of Kamioka and Asofu is about 460 acres, Jabarahira about 60 acres, and Higashi-urushi-yama 25 acres.

Geological Formations and Ore Deposits:—The rocks are crystalline limestone containing amphibolite gneiss of the Archaean Era. It courses from north to south with 50°–70° dip in the form of synclinal. All the mines are located around the Nijiugo-yama. There are more than ten veins, of which the principal are Kobake, Rokusho, Moku, and Aka veins in the Mayebira Mine. They are parallel to each other and nearly vertical. Sometimes they dip to the east. On the west of Nijiugo-yama there is the Kumagai Vein coursing N. 15° E. and dipping E. on its upper part and west on its lower part. To the south of this vein there is the Zuridani Vein. On the east of Nijiugo-yama there are two parallel veins of galena which course N. 30° E. and dip E. They travel to Odome, Higashibira, and Zuridani. To the north of the Kumagai Vein there is the Sugezawa Vein N. 25° E. and to the east of it the Ohdome Vein courses north 60° E. and dips S. 60°. The Tochibora Vein, to the north of the Sugezawa, courses north to south. These veins probably cross cut each other and some faults may be found. In their narrowest part, they are from one to two feet wide, and in the widest part some 10 feet wide. The Odome and Sugezawa veins, where they cross each other, are extremely rich in ore. The vein stuff is actinolite, epidote and often contains calcite, quartz, and plagioclase. These latter are found in the richest part of the Odome Vein. The ores are argentiferous galena and chalcopyrite associated with zinc-blende, tenorite, malachite, and chrysocolla. The champion lode in this mine may be the Odome Vein. In Jabarabira mine, to the north west 1½ mile from Odome, two other parallel veins strike north 10°–20° east and dip 60°–70° to E. They are very wide (30–40 meters) also they are very rich with argentiferous galena chalcopyrite and zinc-blende.

At Higashi-urushi-yama, to the north about 1½ mile from Jabarabira there are also three veins of galena and copper pyrites containing a

certain portion of silver. All these mines as well as the Mozumi Mines are at present worked by Messrs. Mitsui & Co.

Grade of Ores:—There are several different ores, but they may be divided into two great classes, the earthy and stony. The stony ore consisting of zinc-blende with a little galena is rich in silver, containing about 0.035 % of it. The earthy ore, which is still richer, contains on an average, 0.050 % of silver.

Levels and Shafts:—The longest level measures some 3,000 feet and all the levels taken together are over 500,000 feet long. In the levels, railways are constructed.

The shafts are all some 100 feet deep and are mostly used for hauling out the ores extracted. A few of them are used as passages for mines.

Cost of Mining:—The cost of mining the hard ore is about 1 *yen* per 100 *kwamme* of raw ore and that of the earthy ore about one half as much.

Position of the Mill:—The mill is about 2,500 feet below the pit mouth. The ore extracted is first sent to the Dressing House and thence to the mill which is at the lowest part of the claim. i. e., at Shikama-dani, in Funatsu-machi.

Metallurgy known prior to the Restoration (1688):—Before 1887 the stony ore was crushed by manual labor and the galena so separated was washed, smelted, and had its silver extracted by the old process, and much of the silver was lost. Of the earthy ore, which is naturally unfit for being subjected to the washing processes, only the richer portion containing about one percent of silver, was picked and worked for silver, adding a certain quantity of lead to it. This process, improper for this kind of ore could yield no great percentage of silver. No better method was known however.

Metallurgy recently improved:—Even after the Restoration no great change in the metallurgical processes had been introduced till

in 1877, Mitsui Chōgorō leased the mines and commenced to work them in proper style and improved all the processes in dressing and smelting.

The argentiferous galena in the stony ore is roasted in a reverberatory furnace and melted at a gentle heat. The roasted ores vary widely in the quantities of silver they contain according to the grade of the original ores, The richer of them are immediately subjected to cupellation, while the poorer is desilverized by the Parkes process. The cupelling furnace used is of the English type.

That portion of the stony ore, which is unfit for washing like galena, is carefully picked, smelted in the blast-furnace, and made into a matte rich in silver. This matte is then well roasted, fused with a portion of litharge, and then desilverized by cupellation. The litharge left after this desilverization is reduced into lead, which often contains over 0.04 % of silver, and further desilverized with profit by the Parkes process. The lead produced is directly sent to the market and the silver formed into ingots and sent to the Osaka Mint.

The earthy ore, after being roasted to expel the moisture in a reverberatory furnace, is broken in crushers and rolls, pulverized in Moore's apparatus, and further ground in mortar-mills. The powder thus obtained receives a mixture of 3 or 4 % of common salt and is sent by means of screws to a White's automatic blast-furnace. After about 30 minutes the roasted ore is put into an amalgamation barrel. The amalgam obtained is deprived of its mercury in the ordinary way. The silver thus freed is by no means pure and is therefore refined by cupellation. Treated as above stated, the earthy ore which was looked upon as nothing valuable in ancient times, now yields 80 % of the silver it contains and contributes to the national wealth in no small measure.

Percentage of Extraction:—The average extraction of the two classes of ores is silver 85 % and lead 65 %. The copper, which is merely a by-product, is only obtained in small quantities.

Production Statistics:—The annual production is as follows:—

Silver	about 1,700	*kwamme.*
Lead	„ 60,000	„
Copper	„ 11,000	„

Consumption of Fuel:—The charcoal and wood consumed per year are respectively about 3620 tons or 1,000,000 *kwamme* and 4,500 cords or 576,000 cubic feet.

Cost of Working Ores:—The cost of working the stony ore is about 2.30 *yen* per 100 *kwamme* and that of the earthy ore, less than 2.00 *yen.*

The use of Water and Steam Power:—

2–25	Horse-power overshot water wheels for dressing.	
1–25	Horse-power overshot water wheel	for metallurgical work.
1–30	„ „ „ „	
1–95	„ Turbine	
1–50	„ Steam boiler	

Transportation:—Underground in the main levels, and on the surface there are rails; rails and slides are used wherever permissable. In other places hand-wagons each 250 *kwamme* capacity are used.

Distance to Markets:—

To Tokyo	230	miles.
To Osaka	191	„
To Gifu	108	„
To Takayama	22	„
To Toyama (Yetchiu)	34	„

Percentage of Extraction:—About 7 % of marketable metal is extracted from the original ores.

Consumption of Fuel:—The wood and charcoal consumed per year are respectively about 3,906 cords or 490,000 cubic feet and 800,000 *kwamme*.

Production Statistics:—Annual production is as follows:—

Silver	450 *kwamme*.
Lead	5,274 ,,
Copper	13,730 ,,

Cost of Metallurgical Work:—Some 2.30 *yen* per 100 *kwamme* of ores.

Transportation:—In the levels transportation is carried on by means of railroads and wheel-barrows and on the surface by shoots and railroads. Where there are no railroads or shoots ordinary hand wagons are used.

Use of Water Power:—Two 20 horse-power water-wheels are used. No steam-engines are yet in use.

HADASA COPPER AND SILVER MINE.

Situation :—The Hadasa mine is situated at the village o Hadasa in Gujo-gori, Mino Province, Gifu Prefecture, and is at the height of some 3,100 feet above the sea level. It is 12 miles from the town of Hachiman, 45 miles from Gifu, and 200 miles from Osaka. The site of the smelting works is close to the mine.

General History :—There is no authentic record about the discovery of this mine, but it is sure that, it was worked about three hundred years ago, because it is said that in the year 1590 the mining of argentiferous copper ore and galena was done by Inaba Ukio-no-suke, a feudal lord of Hachiman, by the orders of Taikō.

On January 4th, 1888, a silver vein was discovered by Ohara Norihiro, the present manager, at the distance of 600 feet from the mouth of No. 6 drainage level. These veins are now worked by Kidani Magoroku of Kaga Province.

Geological Formation and Ore Deposit :—The country rock is of quartz porphyry belonging to the Mesozoic Era. There are four chief veins, three of them contain argentiferous copper and galena. The widest part of them is 12 feet, while the narrowest 3-4 inches,—on an average two feet. They course from north to south dipping towards east at an angle of 55°-60°. Another vein carrying silver has its strike east-west dipping northwards at an angle of 50°.

Quality of Ore :—The analysis of ore shows us the following :—

7.500 *kwamme*...Copper		from 100 *kwamme* of argentiferous copper and galena.
0.085 ,, ...Silver		
0.900 ,, ...Lead		

0.220 *kwamme*...Silver } from 100 *kwamme* of silver ore.
0.300 „ ...Lead }

Levels and Shafts:—There are 7 levels and 5 shafts, total length of adit levels is more than 10,000 feet and total depth of shafts 750 feet.

Cost of Mining:—The mining expense for copper ore is 3.15 *yen* and that for silver ore 5.95 *yen* per 100 *kwamme* of dressed ore.

Metallurgy:—The metallurgy is carried on with the old Japanese smelting process. Before the Restoration, owing to rough roasting and dressing of ore they could not smelt a large amount of ore at one charge, and three men were required for one charge of 50 *kwamme* of ore. At present, by taking care in roasting and dressing, one charge is increased to 250 *kwamme* and requires the same number of workmen.

The roasting furnace was very small in former days but it has recently been enlarged and improved: at one charge 800–3,000 *kwamme* of ore can be easily roasted using 25 *kwamme* of wood for 100 *kwamme* of raw ore, and 35 *kwamme* of charcoal for smelting 100 *kwamme* of roasted ore.

Percentage of Extraction:—Percentage of extraction on smelting both silver and copper ores is from 62 to 66 %.

Cost of Smelting:—Cost of dressing, carrying, roasting, and smelting inclusive, is 1.85 *yen* per 100 *kwamme* of ore.

Production Statistics :—The production of silver and copper from the year 1880 to 1892 is given in the following table :—

	Silver in *kwamme.*	Copper in *kwamme.*	Cost of Silver in *yen.*	Cost of Copper in *yen.*	Total in *yen.*
1880 (from July to Dec.)...	2.9147	411.500	699.528	746.531	1,446.059
1881	12.6393	1,571.030	3,054.372	2,910 470	5.964.842
1882	22.0667	3,155.400	4,710.587	5,431.109	11,141.696
1883	44.0864	5 353.900	8,143.018	8,068.798	16,211.816
1884	37.2151	5,607.640	5,946.710	5,763.261	11,709.971
1885	47.1108	6,415.550	7,185.053	5,577.629	12,762.682
1886	45.5395	5,354.390	6,964.463	4,195.287	11,159.750
1887	70.3288	7,642.880	10,566.801	7,009.777	17,576.578
1888	93.5529	8,022.520	14,014.616	11,717.064	25,731.680
1889	192.c6965	8,297.570	28,817.938	9,428.528	38,246.466
1890	218.45534	3,533.029	32,467.161	5,887.194	38,354.355
1891	180.82735	8,074.526	26,967.320	9,461.628	36,428.948
1892 (from Jan. to June)...	114.86825	3,855.840	17,216.320	4,313.207	21,529.527

Water Power :—Utilizing natural advantages, water wheels are used for producing all the power required in smelting work.

Transportation :—Traffic both in and out of the mine is carried on with railroads or shoots for transporting ores, rubbish etc.

ANI COPPER MINE.

Situation:—The Ani mine, is the general appellation of seven mines, named Mukoyama, Makizawa, Kosawa, Kayakusa, Sanmai, Ichinomata, and Ninomata. They are situated in Ani-dōzan Village, Kita-Akita-gori, Ugo Province, Akita Prefecture.

General History:—Of the seven mines above mentioned the earliest discovered and first worked is that of Mukōyama which was located three hundred and twenty years ago. Over sixty years later the Kosawa mine was discovered. The Sanmai and Kayakusa mines were located thirty years later and the three other mines were all discovered and opened one hundred and eighty or ninety years ago.

The following, which has been gathered from tradition and old note-books in possession of the older families in the neighbourhood, is the most certain knowledge that we have of the early history of these mines.

The Kosawa and other copper mines. In 1637 one Zenpachiro from Osaka discovered copper ores in a part of the Kosawa mine locally called Kokuinzawa and commenced to open it in the same year. The story of his discovery is one that requires more than ordinary human credulity to believe, but since it is very generally circulated as authentic among the good people living near the mine, it would not be well to pass by it.

Zenpachiro as we have said, was a peddler and used to go about different provinces with useful or fashionable commodities upon his shoulders. One day in 1636 on his way home he met a young girl. This girl, he found upon enquiry to be a pilgrim of devotion to the imperial shrines in the province of Ise and one of curiosity to Osaka. As she was travelling her weary way all alone, it struck him she was a worthy object of pity. He took her home to his lonely house and

before long they were united as man and wife. But after three years of matrimonial life she felt painfully home-sick and begged her husband to let her go. The peddler granted her request. Before parting she said, "My home is at Kokuinzawa 43 miles from the Port of Yoneshiro. If you are ever at Akita, please come to see me." This was in May 1637. In the fall of the same year the peddler with his merchandise as usual travelled to Akita. True to his wife he thence repaired to the Port of Yoneshiro. Thence he walked 30 miles along the river Yoneshiro to Yoneuchizawa, where there were some twenty houses all occupied by lumberers. No other habitations were to be seen in the neighbourhood. Thereupon he proceeded along the river some 10 miles more and found himself at Sanryozawa, a part of Mizunashizawa. There he saw two farm-houses in one of which he passed a night. Asking the inmates of the cottage where his wife's home was to be found they replied, "About 2 miles hence there is a place named Kokuinzawa. But no persons except a few woodmen from here live there. There is indeed no house in this district beyond our place." Zenpachiro's disappointment upon hearing this knew no bounds, but his desire to see his spouse was not a whit abated. So leaving his merchandise in the cottage he repaired to Kokuinzawa, but nothing save dark forests welcomed him. Even this, however, was not enough to make him give up his purpose. He rambled here and there all day long, till the setting sun revealed to him a few wood-chopper's huts on the banks of a river. He inquired of the woodmen, of whom he saw some thirty, whether they knew where the object of his weary travel resided. The reply was, "Beyond this place there is no house, nor has anybody ever ventured to step into it. It would be, indeed, impossible to proceed any great distance farther." The peddler was never so greatly disheartened and passed the night with the lumberers. Conquered by nature he slept the sleep of a wearied man, when a snow-headed genius appeared to him and said, "The kindness you showed me, when I was a tired pilgrim, I remember with love. I am in reality the God Inari, an old occupant of Kurayamizawa, which lies westward from here. Now I

will give you a treasure. Go west of Kurayamizawa, you will find some precious stones. Take them." So saying the mysterious being disappeared. The peddler did not believe all this. Next morning, however, he went as he had been directed and found an abundance of a gold-colored mineral on the banks of a river. Returning to the woodmen he showed them what he thought was Inari's gift. Hereupon they told him that they had seen large masses of the bright thing he valued so highly, while felling trees in the mountains. Next day he went where they said they had seen the shining rocks and broke off a few fragments for specimens.

After a time Zenpachiro returned to Osaka and showed the minerals he had brought back to some folks, who ascertained them to be copper ores rich enough to be worked with profit. He then went to the Kumano copper mine in the province of Kii where the miners corroborated the judgment of the Osaka folks. Upon this he borrowed a certain sum from a capitalist and hired a few miners from the Kumano mine. With them and necessary materials he started his work, which was in his hands for thirty four long years. Then his capitalist Takaoka Kichiemon, an Osaka merchant, made the mine his own and enlarged the scale of work by opening new pits at two or three places.

The Kayakusa mine was discovered by Kōnoike Zenemon and Kagawa Shirō in 1673; the Makizawa, by Izumiya Kichizaemon in 1704; the Ninomata, in 1705 and the Ichinomata in 1707 by Nagai Kujiuro, Nakamura Ichibei and others. Other mines were discovered and worked by other men and at one time there were eleven different owners.

In 1697 all of them came to be managed by the head of the Akita clan. In 1700 he gave the management of the mines to one Osakaya Kiu-zaemon. Seven years later they were taken back and put under his direct supervision. He held them till the Restoration.

The history of the mines from 1637 to 1790 is unknown, but one fact is reported as certain that in 1708 they were quite prosperous, producing 3,600 bars of copper and lead. For eighty-five

years from 1791 to 1875 the total produce of copper was 693,238 bars, averaging 8,252 bars per year. The cost of production amounted to over 2,775,876.136 *yen* (*i.e.* over 4.004 *yen* per bar), The quantity of lead produced during this period was 36,450 bars, averaging 431 bars per year, for which 107,746.111 *yen* (*i.e.* 2.956 *yen* per bar) were spent.

The Mukōyama Silver mine. When the Mukōyama mine was first opened cannot be ascertained. What is known of it all dates from 1576, when a person whose name is now lost, worked silver ores at Uguchi-uchisawa in Mizunashi Village. For twenty-five years after that the mine was worked with profit. But in 1599 one miner went over to the other side of the brook at the place, opened new roads at Maruyama, and was crowned with a success before unknown. The chief reason for this being that because Uguchi-uchisawa was but a small sett it was unfit to work on any large scale.

Fifty-three years later, in 1652, outcrops of silver veins were discovered at Tozawa, and one Aoyama Shōemon commenced to work them the same year.

The next year good ores were found at Uguchi-uchisawa and Maruyama, which were worked by a company of fifteen with one Sasaki Jiūemon at their head. This was very prosperous, and the so-called Ginzan-machi grew from a mere hamlet into a respectable village with three hundred houses. In the midst of this prosperity the mine suddenly caved in burying 300 miners. Before this, one Goemon had predicted that a sad disaster should occur, reasoning that excavation had been pushed too near the surface of the ground, and urged the miners to leave the pits, calling attention to the change in the light of the lamps and in the ventilation. The ignorant miners, however, had been too much blinded by the richness and abundance of the ore mined to listen to this wise warner, who therefore avoided the danger, but few men following him. The day after he had withdrawn the sad catastrophe occurred, and as has been before said, three hundred lives were lost. This naturally put an end to this mine,

and the survivors turned their attention to Uguchi-uchisawa alone and found after prospecting, workable ores. The year 1659 showed a good harvest, rich veins being struck by one Akō Sajiemon, and it was hailed as the year of the restoration of the Mukōyama mine.

The remarkable discoveries and changes since that time are as follows :—

> In the year 1662 after repairing the interior of the pits at Maruyama, Okawa-shita, Uguchi-uchisawa and other places better ores than before were produced. In the year 1667 the ores became poorer and Ginzan-machi less prosperous, dwindling to only 20 houses. Of the Buddhist temples only one named Zenshōji remained. The miners mostly took to farming. In the year 1676, good ore was found and the village again prospered. In the year 1685 it was less prosperous. A few years afterwards good veins were discovered by Aoyama Shōemon at Toyama and between 1688 to 1703 the mine village became somewhat more prosperous. Sasaki Jiūgobei and others mined at Maruyama-neai and Yamamoto Kihei along the river running beside the Maruyama road on the opposite side of Uguchi-uchisawa over the mountains. Between 1704–1710 the Kozawa and the other copper mines became very prosperous. In 1713 Miyagoshiya Jinzaemon, Hishiya Hichizaemon, Yamamoto Koshichirō, Mimura Kichirozaemon, and others mined at Maruyama Toriashi. Other miners were:—In 1718, Sakaeya Gorobei; in 1727, Murata Sakuzaemon; and in the year 1741–1743 the Head of the Akita clan. The Head of the Akita clan put the mine first under the management of the Makizawa mine office and afterwards of Takahashi Kichigorō, Shido Kozaemon, Ibuki Jinzaburō, and others. The production was not as in the days of yore and the profits obtained were very little. No remarkable event has happened since 1789.

Ore Deposits and Geological Formations:—The copper veins hitherto discovered in the different mines are mostly fissure-

veins varying in width from mere streaks to over five feet. The ores exist in vertical veins. The hanging and the foot walls consist of andesite of Tertiary age. Small crystalline grains of copper pyrites, iron pyrites, and rarely zinc-blende are found interspersed in the veins. Sometimes quartz and large crystals of the minerals just mentioned are found. In a few cases ore deposits are seen at the junction of the andesite and shale.

The silver mine of Mukōyama is west of the Ani river. The vein is very large, in its widest part being over 100 feet and in its narrowest it is not less than 10 feet. The country rock is gray tuff, Both walls cannot be seen, but as we mine upward and downward the ore becomes poorer and poorer, until at last in each case porphyry is reached. It is therefore inferred that this rock limits the veins. In the vein, silver ores exist everywhere, but no ores containing less than 0.004 % are considered profitable.

The color and hardness of the rocks in this mine are various, but they are mostly volcanic. At some places granite is found cropping out and in other places volcanic ash is found.

Mining and Metallurgical Work before the Restoration.

1. COPPER.

Prospecting and Mining:—Before the Restoration (1868) there were two hundred and thirty-nine licenced miners or contractors. Some of them had a pit each to work, others one or more veins in a pit, while others had a certain portion of a vein. A class not included in the above classes, mined a certain place, each for a certain number of hours in a day. Each of them was paid according to the quantity of ore he extracted. The prospecting work was done at the expense of the clan government. Certain mining regulations were established in accordance with the veins prospected, but their existence was almost overlooked in the struggle each made

to get more ore than the rest. Under the system of payment above referred to this was natural enough.

The ore each extracted was carried to his own house and washed in the running stream flowing before the door. Those who had not running streams before their doors, washed their ores in common wash houses kept at the expense of the clan government. The ore thus washed was presented to the officials.

Dressing:—The ore was broken into pieces as small as peas and washed in fine-meshed baskets in water-tanks buried in the ground. The portion left in the baskets was thrown away and that which passed through was divided into two portions, one called *omo* (pure mineral) and the other *kataha* (mineral containing some vein-stuff.) The latter was again treated as above, and the portion that passed through was put into wooden bowls, about two feet in diameter. It was then placed in water, bowls and all, and while waiting for the ore-grains to sink, water and floating rubbish were removed. Water was again poured on to it and the deposit was well stirred up. These operations were repeated until grains of specified size were obtained.

Roasting:—Ore which was smaller than peas had a small proportion of micaceous iron added and wetted with clay-water. The mixture was then roasted and oxidized in a kiln, which was 6.5 feet long, 4.5 feet wide, and 4 feet deep. It had two air-holes in front, at the entrance of each of which 250 *momme* of charcoal were placed. Over the charcoal 12 cubic feet of wood were piled somewhat compactly and over the wood 250 *kwamme* of the mixed ores. The whole was surmounted by as much hay as would completely cover the ores. The charcoal was first kindled and when the fire was too strong, stones were placed at the air-holes to control the draught. For the complete cooling of the kiln two to three weeks were required. Of the charge 80 to 85 % was then sent to be smelted and the rest termed *hane* was added to a new charge.

Smelting:—In smelting it was usual to add some matte to the roasted ore. The quantity of matte added was varied according to the amount in hand, but the usual proportions were 480 *kwamme* of roasted ore and 120 *kwamme* of matte, making a charge of 600 *kwamme* of the mixture. But sometimes roasted ore alone and at other times matte alone were smelted.

The ground was dug about 10 feet deep at the bottom of the hole thus made, a water-way was excavated and covered with stones. In this hole about 6 feet in diameter, stone-walls were made and plastered with clay. At the bottom of this some powdered charcoal was placed and made compact by pounding. Another hole about 2.3 feet in diameter and some 2 feet deep was dug and partly plastered with clay. In it two bellows were planted. In the former hole fire was made the day before smelting to remove moisture. The next day it was filled up with charcoal and was operated upon by the bellows. Hereupon the above-mentioned mixtures and charcoal were thrown in and as they melted and sank down more was added. To smelt 600 *kwamme* of the mixture, it took 10 to 12 days and 180 to 200 *kwamme* of charcoal. The matte produced was again subjected to roasting and smelting processes and the crude copper obtained, was sent to the Kagoyama refining works and converted into refined copper.

The Kagoyama refining works are in Niageba-mura, Yamamoto-gōri on the bank of the stream made by the confluence of the Yoneshiro and Daira rivers over 24 miles below the Ani smelting works. The Ani river joins the Yoneshiro about 23 miles lower from the Ani mine, and about 1 mile lower, the latter joins the Daira. There is a place named Daira some 17 miles higher up the stream from Kagoyama. In Daira there are some good lead mines.

The object of erecting the refining works at Kagoyama was to use the lead from the Daira mine for extracting silver from the crude copper of Ani and also to refine copper and lead. This manner of working commenced over a hundred years ago, is still continued, and from an economical point of view it is perfect. We cannot but praise

the keenness and discretion which led the ancients to select this as a proper place for building the refining works.

The procedure of work at Kagoyama was as follows:—

I.—A sort of alloy was obtained by smelting together 36 *kwamme* of crude copper and 6.6 *kwamme* of crude lead in a small hearth.

II.—The alloy was thrown into a liquating furnace, (a partial method) and the silver and lead contained, extracted.

III.—The remaining copper was put into a so-called *komaru* furnace, smelted, and the impurities were removed. At the same time that the impurities were removed, warm water was sprinkled upon the molten copper so as to cause it to rise gradually in thin pieces. This was done for convenience in the next process. These thin pieces of copper were called *komaru* copper.

IV.—The *komaru* copper was placed in clay crucibles and smelted. The molten copper was cast in moulds made of cotton and hemp cloth, and this casting was performed in a tank of hot water.

V.—The argentiferous lead obtained in II. had the lead removed by oxidizing it in a small hearth made of ashes.

VI.—The lead oxide and hearth-bottom or bottom matter were smelted for obtaining lead.

The refined copper, silver, and lead obtained in IV, V, and VI were sent to markets.

2. *SILVER.*

Bonanzas were prospected for among the broad veins, and only rich ore was extracted.

The process of working the ore seems to have been to roast it in a small kiln 100 *kwamme* at a time, to heat about 30 *kwamme* of the roasted ore with lead in a small hearth, and then to subject the precious metals absorbed in lead to a rude process of cupellation.

Grade of Ores:—The following are the total quantities and percentage grade of the principal ores extracted in 1891:—

Ores.	Raw ores in *kwamme.*	Percentage.	Metals contained in *kwamme.*	Dressed ore in *kwamme.*	Percentage.	Metals contained in *kwamme.*	Compared with original ores.
Copper ...	16,834,614	1.93400	325,581.400	1,807,596	11.9600	204,220.90	74.876 %
Silver ...	2,382,461	0.01157	1,316.723	1,382,518	0.0713	985.92	62.724 %

The dressed ores in the above table are raw ores washed in water.

Levels and Shafts:—As the mountains in this district are all very steep, it has been the custom to work mines by driving levels at their bases.

The first shaft sunk commenced February last year and, as yet, is not deeper than 100 feet.

Dressing:—Washing houses are five in all, two at Kozawa, one at Sanmai, another at Ichinomata, and another at Kayakusa, all in front of the pit mouths. Their construction and the number of machines and implements with which they are furnished vary with the quantity of ore extracted and the nature of the ground upon which they stand. But since the mechanical appliances are nearly the same in all dressing houses, the following procedure is mentioned as applying to them all:—

The ore is thrown into trommels together with water and assorted into six grades. The largest about 20 mm. is concentrated by means of sorting tables and the other five sorts are treated in jiggers. Grain ore smaller than 1 mm. is put in rectangular boxes set obliquely and treated with a current of water. The following apparatus are used in the washing houses:—

Mine.	Power.	Horse Power.	Trommels.	Jiggers.	Crushers.	Stamps.	Buddles.
Kosawa ...	Water-wheel	6	4	9	1	10	4
	Turbine	12	4	18	1	5	6
Kayakusa ...	Water-wheel	12	4	12	2	10	12
Ichinomata...	"	12	4	15	2	6	8
Sanmai	Human power	—	3	9	1	5	4

The average percentages of the dressed ore as above described are :—

Sulphur	23.30 %
Silver	0.0112 ,,
Silica	33.55 ,,
Copper	12.23 ,,
Iron...	20.87 ,,
Alumina	3.35 ,,
Magnesia	6.35 ,,

The silver ore worked on the Mukoyama large vein is carried out by two pits and dressed in three different places. One of the two pits is situated west of the Ani river and the other, 340 feet higher on the opposite side of the mountain. The two communicate with each other, but both are used for taking the ore out merely for the sake of convenience.

The object of concentration in this case is to raise the ore containing less than 0.01 % of silver to ore containing 0.05 % or more of it. The ore is first broken by means of a crusher, and then pulverized by means of a stamp. The portion smaller than one mm. in diameter flows down a board covered with cotton cloth and the metallic portion is allowed to sink into the cloth.

The silver ore treated in the three washing establishments are on an average 35,000 *kwamme* per 24 hours. About 12 % of raw ore is usually shown as the result of the various concentrating processes.

The dressed ore is composed of:—

Sulphur	2.514	%
Silica	87.536	„
Silver	0.065	„
Lead	0.862	„
Copper	0.282	„
Iron	2.268	„
Alumina	5.225	„
Zinc	0.295	„
Magnesia	0.122	„

The machines and implements used in the three washing houses are 5 crushers, 45 wooden stamps, 25 feet of concentrating board, 9 Duncan concentrators, and a 32 horse power steam engine.

Mining and Dressing Expenses:—The mining and dressing expenses in the following table do not include the salaries of employés, taxes, and office expenditures. They are merely the wages of laborers and cost of materials consumed in these processes.

Ores.	Mining exp. per 100 *kwamme* of ore, in *yen*.	Dressing exp. per 100 *kwamme* of ore, in *yen*.	Mining exp. per 100 *kwamme* of dressed ore, in *yen*.	Dressing exp. per 100 *kwamme* of dressed ore, in *yen*.	Mining and dressing exp. per 100 *kwamme* of dressed ore, in *yen*.
Copper	0.5335	0.2462	5.2593	2.4272	7.6865
Silver	0.2139	0.2434	1.7610	2.0036	3.7646

Position of the Smelting Works:—The smelting works where both copper and silver are prepared is at Mizunashi on the east bank of the Ani river, for it is to this place that the ores from the different mines, fuel, and other necessaries are most conveniently transportable.

Metallurgy:—In the copper department, the finer ore is roasted in a furnace with five floors and twenty fire-places. A charge of 250 *kwamme* is put on the first floor, two hours after pushed

on to the second floor, and so on till the last, so that it takes ten hours for the complete roasting, while the rougher ore is roasted in heaps of 3,000 to 10,000 *kwamme* taking about twenty days to roast one charge. The finer ores are often mixed with micaceous copper and iron ores found with the pyrites and moulded into lumps of proper size. These lumps are roasted in heaps as with the rougher ore.

There are two brick blast furnaces each with two tuyers. The charge each receives, consists of 40 *kwamme* of roasted ore and a certain quantity of the more ferruginous slag from the copper making furnace. The quantity of the slag used varies with the composition of the ore and slag, but usually 4 parts of the former and 6 of the latter are taken. The smelting of the ore is often incomplete, first because of the excessive fineness of the ore, second, the vibratory motion of the blast, and third, on account of the sinking of the charcoal irregularly, taking some ore particles down with it before they are smelted. When the ore contains too much silicious and clayish substances, the smelting is also incomplete and moreover the furnace becomes incrusted with fine particles of ore and consequently its internal diameter grows less, causing the fire to rise more through its centre than along its walls. Nose-like protuberances, which often lead to the destruction of the furnace, are frequently found to grow at tuyeres. The greatest trouble with the fine ore, however, is its being scattered about. If, to prevent this the blast is made less violent, the quantity of ore treated at a time must be lessened and proportionately more fuel consumed. To overcome this trouble the fine ore is now made into lumps.

For blasting, Root's blowers are used, the pressure being 1½ inches on the mercurial column.

The ore thus treated is thrice roasted before subjecting it to smelting. The first roasting is done in heaps 3,000 *kwamme* at a time; the second and third roasting in a kiln 8 feet long and 6 feet wide. It usually takes two weeks for roasting the ore in this manner.

The roasted ore is very conveniently smelted in water-jacket furnaces 36 inches in diameter. The two blast furnaces above mentioned are at present not used, because the water-supply is insufficient and also because enough ores are not extracted. A charge for the water-jacket furnace is 54 *kwamme* of matte, and 6 *kwamme* of roasted ore, and .24 *kwamme* of silicious slag as flux. The materials thus smelted are about 5,000 *kwamme* per 24 hours and the fuel consumed, some 10 % as much.

The composition of the crude copper, matte, and slag are follows :—

	Sulphur.	Silica.	Copper.	Iron.	Alumina.	Magnesia.
Matte from blast furnace.	23.70	1.67	33.28	32.63	—	—
Slag from the same	6.60	45.05	0.67	16.49	3.14	11.78
Matte from water-jacket furnace.	17.30	2.12	64.72	16.88	—	—
Matte from the same......	7.70	20.68	1.21	34.81	3.94	13.76
Crude Copper...............	1.845	0.12	95.64	1.61	Trace	—

The crude copper is sent to the Kagoyama refining works and has its silver extracted by liquation. The process pursued is not, however, the old method, but the improved English cupellation. The refined copper thus manufactured is composed of 0.026 % of silver, 98.216 % of copper, 0.410 % of lead, 0.302 % of iron, and small quantities of nickel, alumina, silica, and sulphur.

In the silver department the Augustine process is used. Roasting is done in a three-floored furnace having six openings.

The charge, which is roasted in two hours, consists of 200 *kwamme* of ore with 3 % as much of common salt. The pails used to receive the roasted ore are 2.5 feet deep and measure 8 feet in internal diameter. Their capacity is 800 *kwamme*. The saline solution, usually 1,150° B. in weight and 80° C. in temperature, is sent into it by means of an injector. The precipitate containing about 60 % of silver is made into buttons by the English process. The buttons are cast in moulds each taking 5 *kwamme*.

Improvements in Metallurgy:—The mining, metallurgical dressing and other processes were improved in 1879, (when the mine was under the management of the Government). The cost was considerable. Prior to the accomplishment of these improvements all the mining work was carried on simply and rudely; and consequently only very rich ores were extracted. The present methods, though incomparably superior to the old, cannot be spoken of as any great improvement, because they are nothing but foreign methods adopted to the nature, and circumstances of this mine.

To get rid of the disadvantages resulting from a portion of the ores being too fine, it was first cast in moulds together with clay, and then with lime. With the addition of these substances the object in view was attained, but in the first case, the necessary increase of silica made the melting rather incomplete, and in the second case, the cost rose too high. While these difficulties were a problem taxing, the consideration of the managers of the mine, micaceous iron and copper were found in the veins, and upon trial proved to be the proper and cheap substances for mixing with fine ores to form them into lumps. Preparations are now being made for using them instead of clay and lime.

These improvements achieved, (*a*) the roasting process will be much facilitated (*b*) the smelting more convenient and complete, and (*c*) the cost much lessened.

The ore roasted in a furnace and that roasted in heaps compare thus in composition:—

Roasting.	Copper oxide.	Copper sulphate.	Copper sulphide.
Furnace roasting	5.91	Trace	7.81
Heaps "	8.50	2.90	1.80

Expense of working Ores:—Roasting fine ores takes 3.27 *sen* per 10 *kwamme.*

Roasting lump ores costs 1.5 *sen* per 10 *kwamme.*

Formerly it was very costly and consequently almost profitless to work the silver ore, as it contained a very large quantity of silica, but since the adoption of the Augustine process in 1887, it has become profitable.

Production Statistics:—The produce of the mine varies every year. The following is the average for the last three years:—

(1). Refined copper.................... 184,715.710 *kwamme.*
(2). Silver .... 897.901 „

Percentage of Extraction:—The losses incurred during the dressing and metallurgical processes are not by any means inconsiderable and make the percentage of metals extracted from the original ores very low. The ores must, however, be washed before subjecting them to metallurgical operations, for they are too poor to be directly worked.

The copper and silver produced are respectively about 92.957 % and 80.235 % of the molten ores, but as the original ores lose, the copper ore 25.124 % and the silver 37.276 % while being washed, the production ratios in comparison with them, are copper 69.02 % and silver 50.326 %.

The Cost of Manufacturing:—

100 *kwamme* of Copper ore .... 2.814 *yen.*
„ „ „ Silver „ .... 2.257 „

The above is the average expenditure in the manufacture of copper and silver in 1891, but it does not include the salaries of managers and clerks, taxes, office expenditures, etc., only the wages of the smelting laborers and cost of materials used in the manufacture being considered.

The Use of Water and Steam Powers:—

1–30 Horse-power steam boiler.
3–20 „ steam boilers.

2–8	Horse-power	steam boilers.
1–6	"	steam boiler.
2–12	"	water wheels.
1–6	"	water wheel.
2–3	"	water wheels.
1–12	"	turbine.

Transportation :—All the larger levels have either single or double line railways upon which hand or horse wagons are employed. The smaller ones have railways, or wooden tramways and upon them Hungarian tubs are used. The rails used are of cast steel and weigh five kilogrammes to the metre.

From the different mines to the mill, in some parts, wagons freighted with ores run, upon railways. In the ravines, where it is impossible to construct railways, horses and oxen are employed. It is now the intention to make wire-rope tramways in such places.

From the Midzunashi Smelting Works to the Kagoyama Refining Works, and from Kagoyama to Nojiro, transportation is carried on by means of junks. The Ani river being navigable this is very convenient.

ASHIO COPPER MINE.

Position :—The Ashio Copper Mine is situated in lat. 36° 30′ north, and long. 130° 30′ east, at the town of Ashio, Kamitsuga-gori, province of Shimotsuke, Tochigi-ken. The sett is about 13 kilometers in circumference, and is nearly surrounded by lofty mountains. The highest peak is 1323 meters above sea level. The smelting works and central office are in a valley close to the mine at the height of some 640 meters above the sea. With such a situation it is easy to imagine how great the difficulty of transportation must have been in former days. At present, however, there are two fairly good roads passable by horses and wagons, one 27 kilometers to Nikko in the south-east, and the other 43 kilometers to Omama in the south-west. A few years ago two railway stations were opened, one at Nikko and one at Omama, greatly facilitating the means of transportation and communication.

General History :—Of the discovery of the mine there is no authentic record by which it can be ascertained, but tradition puts it as far back as the year 1610. Since then until the Restoration in 1868 it was worked under the direct control of the Tokugawa Government. It was then transferred to the provincial government. The vicissitudes, it underwent during this period of over 200 years, are by no means certain, only the following facts being on record :—

1.—That for some years since 1614 one-fifth of the total yield of the mine was exported to Holland.

2.—That in twelve years between 1676 and 1687, thirty-two furnaces were constructed which yielded 1320 to 1500 tons of refined copper per year.

3.—That 1,206,450 plates of copper tiles were manufactured for the Yedo Castle in September, 1708.

4.—That all the copper tiles used for building the Nikko, Shiba, and Uyeno Shrines were manufactured here.

In 1871 the mine which had been worked by a private party was transferred to its present owner Furukawa Ichibei.

In 1877, when it was in its poorest condition, it yielded only 48 tons of coarse copper during the year. Since then Mr. Furukawa with diligence and enthusiasm has tried to improve all the works, and enormous sums of money were judiciously expended, with the result to increase the product year by year until last year when it yielded 6,000 tons of coarse copper.

Claim :—The whole claim measures 53,964 hectares in area, besides 3,287 hectares of attle heap or rubbish claim.

Geological Formation, Ore Deposits and Ores :—The principal rock at this mine is dacite which extends, 4 kilom. from north to south and 2,200 m. from east to west. It is surrounded by clayslate and hornstone of the Palæozoic age. Broken pieces of rocks belonging to the group are often found among the dacite which makes it evident that the latter rock erupted through the palæozoic rocks. Besides the above rocks, there crop out in many places syenite, augite andesite, and other rocks, but they are not so rich in metalliferous veins as the dacite and palæozoic rocks.

There are several hundreds of metalliferous veins, but the most important are the six champion lodes now worked, which run parallel to one another coursing S.W.–N.E. and dipping to N.W. at an angle of 60° to 70°. The widest outcrop is 5 m. in breadth and the veins measure 300 mm., to 2 m in width averaging 600 mm., of which the available portion ranges from 150 mm. to 1½ m., or say 300 mm. on the average.

The chief ore is rich copper pyrites often mixed with erubescite and rarely with chalcocite, melacconite, azurite, etc. The gangue is

commonly quartz. The following show the composition of one of the principal ores :—

Insoluble matter	27.14
Copper	21.15
Iron	23.49
Sulphur	27.14
Alumina	0.79
Lime	0.24
Magnesia	0.04
Silver	0.01
	100.00

The more impure ores contain besides the above substances, small quantities of arsenic, antimony, and tin, with traces of bismuth, cobalt, nickel, and other elements.

Mining :—Formerly the levels were very narrow and tortuous so that the working was very difficult, but since 1877, they have been enlarged to a proper size.

The levels worked at present are five; the Hon-kuchi, Ariki, Sunoko-bashi, Kotaki, and Otsūdo, the last being the drainage level.

The Honkuchi Level (2.12 m. high × 2.42 m. wide) is situated 84.84 m. above the office and is 1,158 m. long. It is laid with a double-line railway. Within the upper 273 m. of this level, there are 12 large drifts and 13 shafts, and below there are sunk several smaller shafts and one main shaft (4.54 m. × 3.21 m.) 87 m. deep, which communicates with the Ariki level. Along this main shaft there are 4 levels driven.

The Ariki Level (2.12 m. high × 2.42 m. wide) is located 87 m. below the Honkuchi level. It is 2.045 m. long. and is run by a single-line railroad. At 1,440.60 m. from the mouth, there is a main shaft, 80 m. deep, in the same vertical line with that of the Honkuchi level. From this main shaft there are 5 drifts. Besides this the Ariki level has another shaft with 4 drifts, and 4 smaller shafts.

The Kotaki Level (2.42 m. high × 3.30 m. wide) is located at the back of the Honkuchi, 36 m. lower than the Ariki level. It measures 2,090 m. in length. In its upper portion it has 5 greater drifts and 16 shafts, and lower 3 greater drifts and 10 shafts. Besides these, this level has a main shaft, 64 m. deep, 4.09 m. long. and 1.90 m. wide.

The Otsūdō (2.90 m. high × 3.03 m. wide) is a drainage level situated to the south of the Honkuchi, 162 m. lower than the Ariki. It is 3,100 m. long. and is being driven towards N.W. The main object of this adit level is to attain communication with the Ariki and Kotaki levels thereby draining them and also to answer the purposes of transportation and ventilation. The excavation of this adit level was commenced in September, 1885 and is still continued, using three rock-drills driven by compressed air which is supplied from an air compressor worked by a 150 horse-power turbine. Upon the completion of this level, it will reach 162 m. below the Ariki level and from which it is estimated that ores sufficient to yield 500,000 tons of refined copper, may be mined.

The total length of the drifts and shafts belonging to the five levels are as follows :—

Drifts.

Honkuchi level	21,985 m.
Ariki level	5,030 ,,
Otsūdō and Sunokobashi level	4,170 ,,
Kotaki level	10,686 ,,
	41,871 m.

Shafts.

Honkuchi shafts	2,352 m.
Ariki shafts	314 ,,
Sunokobashi shafts	285 ,,
Kotaki shafts	1,479 ,,
	4,430 m.

Where rapid work is desired, rock-drills are used, dynamite and electric fuses fired by a hand blasting machine being the explosives employed. Seven drills are now in use in the Otsūdō, Ariki, and Kotaki levels.

The Extraction of Ores:—The object in this part of the work is only to get a certain portion of a vein. Labourers, wages are fixed every half month upon examining the thickness of veins, composition of ores, etc. the places to be worked being fixed by lot. At present there are 311 working places from which the ores are extracted :—

Honkuchi level	91 places.
Ariki level	79 ,,
Sunokobashi level and Otsūdō	16 ,,
Kotaki level	125 ,,
	311 places.

One labourer extracts on an average 150 kilog. of ore in a shift of 8 hours, using gunpowder, dynamite, safety fuses, etc. The cost of mining per ton of ore is 10.32 *yen*. Last year the different levels yielded ores in the following proportions :—

Honkuchi level	54.75 %
Kotaki ,,	41.97 ,,
Sunokobashi and Otsūdō	3.28 ,,
	100.00 %

Ventilation:—This is for the most part left to nature. In some places it is aided by properly placed doors to direct the air into desired portions of the workings. When there is especial need, however, regular ventilators are used, or a part of the compressed air for driving rock-drills is utilized.

Drainage:—The water in the upper portion of the Honkuchi level is drained from that level, while that which is below together with that below the Ariki level is removed from the latter level.

As already stated, the Ariki level is directly beneath the Honkuchi so that the greatest quantities of water accumulate in the Ariki. In 1890, an electric plunger pump made of phosphor bronze was fixed at a depth of 80 m. in the main shaft of the Ariki level. The barrel of this pump is 450 mm. in internal diameter and the length of stroke is 480 mm.

It can raise 1,530 litres of water from a depth of 79 m. in one minute. At present only $\frac{1}{4}$ of this quantity is raised. The power required is produced by a 90 horse-power motor placed at the mouth of the shaft, which is connected with a dynamo-machine by means of a copper wire (2,120 m. long.) and a cable (910 m. long.) For use in cases of accident 4 Blake-pneumatic pumps which can lift 541,000 litres of water to a height of 61 m. in 24 hours, and Tangies special pumps lifting 902 litres of water to the height of 152 m. in 24 hours, are stationed close to the electric plant and also at No. 3 drift which is 45 m. below the shaft mouth.

In No. 4 drift of the Ariki level situated 60 m. under the latter, there are 2 Tangies special pumps which drive the water out by No. 1 shaft into the Ariki level. These four pumps are supplied with steam from 5 boilers (150 nominal horse-power) while the pneumatic pumps are supplied with compressed air from a Rand air compressor which is moved by steam from 3 steam-boilers (180 nominal horse-power).

The Kotaki level has 4 Blake plunger pumps, each lifting 454 litres in a minute, two of which are always working and the other two kept in reserve against accident. These pumps are moved by compressed air furnished by air-compressors worked by a 100 horse-power turbine. For use in cases of freshets there are, at No. 2 level, 4 Blake piston pumps made to run by steam power from a 40 horse-power boiler planted at the mouth of the adit-level. For temporary use hand pumps are used.

Transportation :—The ores are carried out of the levels by means of wagons run on rails whose gauge is 500 mm, The rails

weight 5 kilog. per metre. They run 37,035 m. in all distributed as follows :—

Underground railroads	27,456 m.
Overground railroads................................	9,579 „
	37,035 m.

The wagons are made of wood, each of them carrying one ton. They are drawn by men, but in the Ariki level, where the greatest quantities of ore has to be handled, horses are employed.

The main shaft in the Ariki level is provided with an electric winding engine. The drum and the winding rope are respectively 2 m. and 30 mm. in diam. This engine winds 2 tons of ore from a depth of 152 m. below the Ariki level in 2 minutes. The electricity is furnished in the same manner as it is furnished to the electric pump.

Ore Dressing :—Up to 1883, the old methods of dressing had been in use. They were very rude and were consequently very uneconomical. Since 1883 a great many improvements in the dressing processes were carried out, and many machines were built. The machines now employed for this part are as follows :—

8—Blake's breakers.
2—Cornish crushing rolls.
2—Washing trommels.
20—Sizing „
36—Single jiggers.
5—Fine sand jiggers.
30—Stamps.
9—Duncan concentrators.
200 H.P.—Prime motors (steam-engine, and turbines).

In this mine only the metallic portion of a vein is mined. From this samples are taken and examined in order to determine the rates of wages, before the ores are sent to the dressing department. The ores undergo, as it seems, a preliminary sorting in the mine before

they are delivered to regular dressing, therefore, the work in dressing is comparatively more manual than mechanical.

At present the daily production of dressed ores is 110 tons of which 60 % come from handpicking and the remaining 40 % come from mechanical dressing. The dressing processes are as follows: The ores are first thrown on an inclined grate sorting them into two sizes. These are handpicked into three sorts (a portion thus made ready for roasting). The larger pieces left over, go to the Blake's breaker, and the smaller to the Cornish roll. Under the former trommels are placed and under the latter there are several sizing trommels arranged in steps. The remaining portion is dressed by means of jiggers and what still remains, together with that portion which did not go to jiggers, is stamped and afterward sorted by means of Duncan concentrators. The tailings left after these processes were until recently laid aside as of no value.

The supposed useless tailings, however, have been found to contain some copper, and therefore a special building has been erected and furnished with the under-mentioned machines it having been estimated that some two tons of dressed product might be obtained from 3,600 kilolitres of the tailing-slime per 24 hours :—

6—Sand classifiers.
8—Fine sand-jiggers.
4—Double revolving buddles.
3—Evan slime tables.
3 rows of slime sorting boxes.

The Kotaki dressing work is now being improved so as to enable it to yield 90 tons of dressed product in 24 hours, and the following machines are to be employed :

2—Blake's breakers.
3—Krom crushing rolls.
4—Huntington mills.
4—Double revolving buddles.
3—Evan slime tables.

14—Sizing trommels.
2—Washing trommels.
7—Slime sorting boxes.
2—40, horse-power steam-engines.

These two works we hope to see well finished in September.

METALLURGY.

a. **Metallurgy prior to the Restoration**:—The old smelting process practiced here is very simple. A ton of dressed ore is put into a pit 1 m. in dia. and by 2 m. deep, built of stone blocks in the ground. Here it is roasted for 15 to 20 days, and then the roasted ore is subjected to a smelting process.

Smelting:—The smelting hearth is made in the ground with the walls of stone cemented with clay, and lined with brasque. After drying by a charcoal fire, it receives a charge of one ton of roasted ore together with 564 kilog. of charcoal. Blast is produced by bellows. The smelting is completed in 6 hours. The slag is then raked out and the matte formed, is cooled on the surface either naturally or sprinkled with water, and is stripped off into thin sheets. The remaining molten metal is ladled into moulds. This operation is repeated twice in a shift of 12 hours.

The matte thus produced is roasted in pits similar to those which were used for the raw ores roasting and smelted again into black copper.

b. **Metallurgy after the Restoration**:—For 15 years after the Restoration the old method alone was used, but in 1883 oxidation of the matte was effected by heap roasting, while for roasting ores three reverberatory furnaces were built. Furnaces of this description have since gradually been added, so that there are now ten of them.

In 1884 old style hearths were increased and hand-bellows were replaced by Root's blowers driven by steam.

In April 1887, an American water-jacket furnace, 1 m. in internal diameter, with 5 tuyers, was erected, but before its efficiency had been

fully experimented upon, it was accidentally destroyed by fire. In November of the same year, three Pily furnaces, 1,500 mm. in internal diameter with 8 tuyers were erected. In December 1889, the mine had 63 of old fashoned hearths and 3 Pily furnaces.

Neither the Japanese nor the Pily furnaces were satisfactory, the chief drawback of the latter being insufficient blast for so large a diameter. Next so a rectangular shaft furnace was contrived which showed itself quite satisfactory. Consequently, since April, 1890, furnaces of this kind alone were erected and now there are 13 of them in use. Through the success of these furnaces, the use of Japanese and Pily furnaces was entirely abandoned in December of the same year, opening a new era in the metallurgical system of this mine.

Before entering upon the description of the new system of work, it will be better here to describe the structure of the above-mentioned rectangular shaft furnace and the reverberatory furnace.

The reverberatory furnace is internally 36.40 m. long 2.13 m. wide. It has 12 working doors and one fire door all arranged on one side.

The rectangular furnace measures 2.20 m. from the tuyers to the top. Its horizontal section is internally 1.50 m. long by 0.80 m. wide at the tuyers. The shaft is surrouuded by a water jacket 0.80 m. in height in the hottest part while the other part of the shaft flue and hearth are made of fire bricks. The water-jacket furnaces have 12 tuyers, 4 on each longer side and 2 on each shorter side. A dust chamber is provided to accumulate the metallic dust carried along the smoke from the furnace.

Roasting:—The smelting work, daily receives about 110 tons of dressed ore, containing on the average 18 % of copper. The different sizes are in the following proportions:—

a.	Lumps above 40 mm. in diameter.	40 %
b.	Grains above 7 mm. in diameter.	30 ,,
	,, ,, 4 mm. ,, ,,	20 ,,
c.	Sands and slimes.	10 ,,
		100 %

These different ores are roasted as follows :—

a. The lump ores are roasted in heaps in the open air or in oven stalls.

b. The sandy ores are calcined in reverberatory furnaces using wood as fuel. One such furnace yields 510 kilog. of roasted ores per hour and 12 tons per 24 hours, consuming 3380 kilog. of fuel. The charge is introduced into the furnace at its coolest part and is transferred gradually into the hottest part stirring it occasionally.

c. The slimy ores are first moulded into bricks with clay after which they are roasted in ovens.

Smelting :—In this section the smelting of the ore and matte is performed in one and the same furnace.

The charge is, of the following nature and composition :—

Roasted ore...........................	1,000	kilog.
„ matte........................	300	„
Cupriferous slag.....................	150	„
Limestone	180	„
	1,630	kilog.

Each furnace smelts about 28 tons of this mixture per day, consuming 250 kilog. of wood for each charge.

A charge, as it melts down, flows into the fore hearth and there separates into slag which flows out from the slag spout, the matte, containing about 40 % of copper, which has to be roasted and smelted again and the black copper, containing about 94 % of copper, which is moulded into ingots and sent to the Copper Refinery at Yanagiwara-chō, Honjō, Tokyo, to be refined and exported.

Percentage of Extraction and Expense of Working:— The dressed ores, containing 18 % of copper, yield about 88 % of the metal they contain. The expense of metallurgy is 45.00 *yen* per ton of crude copper.

Improvement in Metallurgy :—The above-described method of metallurgy based upon English and German methods, efficient as it

is, has still the drawback of requiring enormous quantities of fuel for repeated roasting and smelting before we get finished products.

A method of copper smelting called the *Mabuki* process has been practiced in this country from ancient times. This yields good marketable copper by a single roasting and smelting, and is the most efficient and economical method known.

For this reason it has been decided by the managers of the mine to adopt this process, but the so-called *Mabuki* furnace in its present form, can only produce 370 kilog. of copper per day, and therefore is insufficient for use in this mine. It is now being enlarged and otherwise improved.

The Improved Mabuki Method:—The *Mabuki* method comprises two stages:—

1—Preparation of matte in shaft furnaces.

2—Preparation of copper in converters.

The converter resembles the Bessemer converter with horizontal tuyers patented January 1862 and is 1.70 m. internal diameter and 2.50 m. high. The shell is of wrought iron lined inside with a refractory silicious substance. Twenty tuyers each 15 mm. in diameter, are horizontally arranged around the body at 300 mm. from the bottom. This last 16 times (*i. e.* for 18 hours), taking a charge of 2 tons at a time, and yielding on an average, 700 kilogram of ingot copper per hour.

Iron oxides formed during the operation injure the silicious lining very much which therefore often requires repairs. Hence four such converters are provided and used in turn two at a time.

The Blowing Machine:—The blowing machine used forces out 650 litres of compressed air (with a pressure 500 mm. mercurial column) in one second. It is of 77 horse power and the steam is supplied from three steam boilers, each of 30 horse power. The manufactures of this machine are Fraser, and Chalmers Co., Chicago, U. S. A.

The Matte melting Cupola Furnace:—This is for smelting the matte, before it is introduced into the converter. It measure 1 m. internal diameter at the tuyers. It is blown by means of 6 Roots' blowers, melts 1.8 to 2 tons of matte per hour.

The Procedure of the Work:—The matte from the furnace containing 40–50 % of copper is charged into the matte melting cupola and fused. About 2 tons of the fused mass are tapped into a converter and the blast is forced in. After about one hour when the matte is completely reduced, the converter is inclined and its contents ladled out into ingots. The copper thus obtained is about 98 % pure.

Production:—Here follows a table of the production since it has come under management of the present owner.

Year.	Crude Copper in tons.	Year.	Crude Copper in tons.
1877	56.216	1885	4,141.741
1878	48.984	1886	3,638.130
1879	91.080	1887	3,631.790
1880	92 488	1888	4,124.108
1881	174.259	1889	4,901.618
1882	293.650	1890	5,862.316
1883	655.028	1891	6,099.248
1884	2,314.971	1892	——

The *Mabuki* smelting work will be completed in November next, and its efficiency will be 6,000 tons of ingots per year. Its completion promises a favourable revolution in various parts of the metallurgical work of this mine.

Fuel:—The mine is fortunately situated for fuel as any quantity of wood and charcoal can be obtained at reasonable rates from a distance of ten to twenty-seven kilom.

The quantities and cost of fuel consumed last year are :—

Fuel.	Quantity in tons.	Cost in *yen*.
Charcoal	18,000	148,400
Wood	35,900	60,500

So much was consumed last year, and it may be inferred that as much will be required in after years for the production of 7,000 tons of crude copper per year. But when the *Mabuki* works above described and water power appliances to be hereafter mentioned, are completed, it is reasonably hoped that the consumption of fuel will become considerably less.

Besides, it being the intention of the proprietor of the mine to use more coke and less charcoal in the future that the benefits of the surrounding forests may forever be enjoyed, there seems to exist no cause for fear as to want of fuel for many years to come.

The Use of Steam, Water, and Electricity :—The power employed in this mine is about 1,600 horse-power :—

Mining	760 horse-power.
Dressing	320 „
Metallurgy	250 „
Work shop, haulage, electric-light, etc. ...	270 „
	1,600 horse-power.

In order to produce this amount of mechanical force, a quantity of fuel worth 221,000 *yen* per year must be consumed (8 kilogram of wood per horse-power). But what is fortunate, this mine is rich in water-power for utilizing which during the last few years various contrivances have been tried. About 70 % of power needed in the different departments of the mine is afforded by this natural agency. This means an economy of 63,500 tons of fuel costing 12,700 *yen*.

Turbines already Constructed:—

Excavation and dressing (1886)	1–150 horse-power.
Excavation and ore extraction (1888) ...	1–100 „
Metallurgy (1889)...........................	1– 80 „
Hoisting fuel (1891).........................	1– 8 „
	338 horse-power.

Hydraulic Motors in Reconstruction:—A dam is constructed 3 kilom. above the place where a Dynamo is planted. From the dam a wooden canal 1.2 m. wide by 0.8 m. deep starts and after running along the mountain side for 4 kilom. with an inclination 3 in 1,000 reaches a points above the turbine giving every second 1½ cub. m. of water with a head of 31 m.

A large German turbine of 400 horse power was once used, but because it was so complex in structure that it often got out of order and also because its efficiency never exceeded 50 %, it was given up and five simple Pelton wheels each 1.30 m. in diameter, revolving 160 times per minute, and yielding 100 horse-power, were erected in its place. With these wheels however great the head of water may be, their efficiency is high, also their construction is so simple that they seldom get out of order.

Dynamo:—The force communicated to the Pelton wheel is converted into electricity by 5 Siemens dynamos, each of 90 horse-power. The electricity is again converted into motive force by a motor placed at a distance of about 4 kilometers. Five copper wires, each 12 mm. in diam. are used.

Distribution of Power:—This power is distributed as follows:—

Drainage	120 horse-power.
Winding engines	50 „
Rock drills	90 „
Blowing engines	100 „

The loss due to resistance is 20 %.

Turbines in Construction:—

1–100 horse-power turbine at the Otsūdō level.
4–120 ,, turbines for wire rope tramway.
1–80 ,, turbine for metallurgy and electric light.

All these plans being completed the water power utilized will amount to 1,000 horse power which is, as before stated, about 70 % of all the motive power of the mine.

The Electric Light and Telephone:—Incandescent lights and arc lights are used in various parts of the mine, a dynamo (volts 60, amperes 90) being employed.

Upon the completion of the hydraulic arrangement it is hoped to have electric lights, in the different departments of the mine by two dynamos (volts 225, amperes 90, each.)

The telephones are Gabel's and Siemen's. The wires, the total length of which is 61 kilom. run to the branch office in Nikkō and the different departments of the mine from the Central Office, where the exchange is arranged.

Transportation:—The different roads about the mine were formerly very bad, and could only be passed by horses and oxen. Since 1884, however, by expending tens of thousands of *yen*, most of them have been so far improved as to make them passable for wagons. This improvement has not yet been quite satisfactory for the most important of these roads, *i. e.* the one leading to Nikkō, running over a very steep pass, can by no means be traversed by wagons, and it may be necessary to excavate a long tunnel. The inconvenience and trouble unavoidable under such conditions have been most painfully felt during the rainy and snowy seasons. Between August to October 1890, these inconveniences and troubles were removed by constructing a Roe and Bedlington single line wire rope-way. The upper and the lower end of this tramway, where stations are placed, are respectively named Jizōzaka, where there is a 15 horse power stationary engine, and Hosoo. It has 17 posts and 87 hangers.

The total length of the wire is 7,350 m. and 100 tons may be transported in 24 hours. The longest spans are 550,423 and 350 meters. Maximum load per basket 200 lbs. Spacing 100 meters speed 50 meters per minute. This is the first wire ropeway erected in Japan.

A second wire ropeway has been constructed for the conveyance of charcoal. It is of the same style as the first.

It has 26 posts, and a length of 3,300 m. It is worked by a 15 horse power engine. It can transport more than 40 tons a day.

A third wire rope tramway also for charcoal transportation is now in construction. The total length of cable is 9792 m. There are 24 posts and 130 baskets. The upper and the lower station ends are respectively called Mochigase and Bunzō. It is worked by a 40 horse power Pelton water-wheel and conveys 6 tons per twenty four hours.

These methods of transportation, good as they are for their intended objects, are not quite equal to the growth of the business of the mine, and therefore in January last year, a regular tramway was commenced. It is yet in course of construction.

This tramway will have a length of 36,806 m. It is estimated to be more than enough for carrying 60,000 tons per year which is proportioned as follows:—

Carrying out crude copper	7,000 tons.
Taking in machines, tools, coke, wood, limestone, and other things	53,000 ,,
	60,000 tons.

Description of Lines:—The first line, 22,320 m. long, is to run on several public and private roads from the Nikkō railway station to the Watarase central station and thence to the Central Office. The first wire rope tramway is to be used from Hosoo to Jizōzaka. The second line, 1,810 m. long, to Otsudo. The third line 6,838 m. long, to Kotaki. The fourth line 9,850 m. long, to Sawairimura from the Watarase on public and private roads.

General Outline of the Work:—Lines are generally single except where for special reasons it is necessary to make them double. Single private roads are to be made 3 m. 50 mm. wide, those on public roads, 1 m. 830 mm. and where double, 4 m. 880 mm. wide.

The bridges, 112 in all, are to be 3 m. 50 mm. wide. They are truss bridges, constructed with wood. The bridge before the main gate is to be an iron bowstring bridge with a width of 4 m. 575 mm. The rail weigh 8 kilog. per metre, the gauge is 610 mm. The grade is 1 in 20 m. The wagon are 2 m. 440 mm. long and 2 m. 220 mm. wide. They are furnished with brakes and those for passengers with brakes and springs.

Conclusion:—The Central Office and Kotaki lines from Jizō-zaka through the central station were finished in July last year and the Sawairi line in September. The Hosoo-Nikkō line will be commenced as soon as the Government gives permission to use the public highway.

Upon the completion of this tramway, the transportation system will be entirely new much to the good of all connected with it.

Since the different lines run along water courses, water power can easily be utilized, and therefore it may happen that horses will be superseded by electricity.

BESSHI COPPER MINE.

Situation:—The Besshi Copper Mine is in the mountains running from east to west between the provinces of Iyo and Tosa in the central portion of Shikoku. The pits now worked are at Ashiya in Besshiyama Village, Uma-gori, Iyo Province and go under the name of the Ashiya mines. The pit mouth is over 3,600 feet above sea-level.

General History:—This mine was discovered in 1690 and located on the first of August, 1691, by an ancestor of the Sumitomo family, by name Sumitomo Kanbashi.

The circumstances of the discovery and location are as follows: One Chōbei, a miner employed in the Tachikawa copper mine in Nii-gori, Iyo, secretly knowing of the existence of large copper ore outcrops in the Besshi mountains, went, one day, to the Yoshioka copper mine in Bitchiu, then the property of Sumitomo Kanbashi and related his secret to the director of that mine. The latter believed Chōbei and repaired to where he directed him. This was somewhere between 1684 and 1687. After careful prospecting work and thereby ascertaining the richness of the veins and also the abundance of good fuel in the neighborhood, he applied to the Tokugawa Government to permit his employér, Sumitomo Kanbashi, to locate a mine there. The desired permission was obtained in 1691. He started work in the same year. The new mine grew in prosperity so rapidly that the proprietor of the Tachikawa copper works became envious of his neighbor and did much to prevent the growth of the new work. He even went so far as to prohibit the men of the latter mine from passing through Tachikawa-yama village. This made it necessary to build a road in the steep mountains east of the new mine and eventually to buy the Tachikawa property at an enormous price.

Since 1685 year by year the production of copper grew more and more abundant, until it exceeded 2,000,000 *kin* per annum. Subsequent to this prosperity the mine suffered in consequence of the excessive rivalry with the neighboring mine and also in consequence of natural catastrophes. Still it was never left idle even a year and the average annual product did not fall under 1,000,000 *kin* until the Restoration. Since that memorable year much has been done in the way of improvement, the result of which is the present prosperity.

Geological Formation, Ore Deposits and Quality of Ores :—The principal rock is mica schist belonging to the Archaean Era. Crystalline hornblende, quartz, serpentine, and other rocks are also often found.

The ore deposits are in a vein coursing north 30° east, and dipping 48°. It is over 5,000 feet in length and it varies from 3 or 4 feet to over 10 feet in thickness. It is often 7 or 8 feet thick.

The ore is copper pyrite containing a great amount of iron pyrites, and the vein stuff is cheifly quartz. The richest ore contains not less than 12 % of copper, but the poorest not more than 2 or 3 %. The average precentage of ore now worked by the usual method is seven. The poorer ore is treated by the precipitation process.

Depth of Shafts and Length of Levels :—A main shaft is in process of sinking along the north side of the vein with an inclination of 49°. It has been sunk 420 metres as follows:—

From the winding engine at the pit mouth to No. 1 level	60 metres.
No. 1 level " " 2 "	80 "
" 2 " " " 3 "	40 "
" 3 " " " 4 "	80 "
" 4 " " " 5 "	80 "
" 5 " " " 6 "	80 "
	420 metres.

It is proposed to sink a shaft from No. 6 level to No. 8 level.

Total length of the main levels is 13,938 feet as seen below:—

No. 1 tunnel	....	4,200	feet.	
New level	....	600	"	
No. 1 "	....	342	"	
" 2 "	....	2,040	"	(E. to W.)
" 3 "	....	2,367	"	"
" 4 "	....	3,119	"	"
" 5 "	....	270	"	"
		13,938	feet.	

Cost of Mining:—The total quantity of ore mined last year was 9,032,074 *kwamme* for which 64,010.122 *yen* were spent, *i. e.* on an average about 70.86 *sen* per 100 *kwamme*.

Position of Smelting Works:—Two dry method and two wet method processes are established, at Ashiya in Besshiyama-mura, Uma-gori, one wet method process at Yamane in Kadono-mura, Nii-gori and one smelting house for dry method at Niihama-mura, Nii-gori.

Metallurgy before the Restoration:—The metallurgical process practiced previous to the Restoration (1868), which Kanbashi, learned of a Chinese named Hakusui, is what is popularly called *Namban-buki*. This is a sort of liquation. It was upwards of three hundred and twenty years ago that Rizaemon learned and practiced it for the first time in this country. Roughly described it is as follows:—

I.—Smelting. A round hearth 1.7 feet in diameter and 1.5 feet deep is first made. Behind this are placed two bellows from which the air is sent into the hearth through two tuyeres in the side. It is used for about 12 hours at a time, during which the ore once roasted and properly mixed with charcoal is thrown in and smelted. A certain quantity of silica is thrown in from time to time to aid the separation of the copper from the slag which is allowed to flow out by the

time the whole charge has been smelted. The copper is pared off as it solidifies. About 600 *kwamme* of ore are thus worked with the consumption of some 70 *kwamme* of charcoal, and 150 to 160 *kwamme* of matte are obtained.

II.—Smelting (continued). Another round hearth 2.3 feet in diameter and 1.5 feet deep with two tuyeres in the back wall is built. The half of each tuyere is provided with a semi-circular cover. The air is sent in from two bellows placed behind the hearth. The copper matte is thrown into this hearth with a suitable proportion of charcoal. The air is sent in from two bellows placed behind the hearth. About 170 to 180 *kwamme* of the matte will be thus fused in two or three hours, after which, with one tuyere completely shut and the other partly closed by means of the semi-circular cover the bellows are brought nearer the hearth and worked actively. In the meanwhile charcoal is continually added in small quantities and the fused mass stirred. After six or seven hours, when the copper and slag will have been well separated, warm water is sprinkled upon the fused mass which is pared off as it solidifies. The result of this process is 50 to 60 *kwamme* of crude copper.

III.—Refining. The hearth used in this process is of the same type as that used in II., only made a little smaller. The manner of blowing is also the same. The crude copper is suitably crushed and 192 *kwamme* of it are worked per day in two charges. This step differs from II. only in this, that pine branches and twigs are thrown into the hearth just before the refining is fully done in order to aid the sublimation of the volatile admixtures.

IV.—Casting. A hearth similar, though smaller, to that used in III is prepared. In it crucibles containing refined copper and charcoal are heated by forcing in the air from bellows placed beside it. The operation is repeated six or seven times a day. Small pieces of pine wood and charcoal are

thrown into the crucibles, the former for facilitating the volatilization of some admixtures in the copper. When the copper is completely fused, oak charcoal is put into the crucibles. When this charcoal is no longer seen, the fused copper is ladled into moulds. The fine copper thus prepared contains upwards of 99.4 % of copper. By repeating the above operation six times it is prepared to the amount of 115 *kwamme* per day.

Metallurgy after the Restoration:—At present the ores are worked in three places, viz; Besshi, Niihama, and Yamane.

The work at Besshi is as follows:

I.—Roasting. Pieces of ore 1 or 2 inches in diameter are roasted in a calcining kiln 24 feet long, 4 feet wide, and 4.5 feet deep. On the bottom of this kiln wood is placed and upon it the ore is heaped. It takes about 60 days to roast a charge.

II.—Ore Smelting. The roasted ore is smelted after mixing with a little silcious matter and charcoal. The furnace used is made of fire bricks 3.5 feet in diameter and 10 feet high. It has four tuyeres. A Root's blowing machine is used with it. It smelts 4 tons of roasted ore and produces a matte containing 40 % of copper.

III.—Matte Smelting. The matte is treated for crude copper in a hearth built of brick, accompanied by a Root's blowing machine and in construction similar to that used before the Restoration. It works 200 *kwamme* of matte per day. The crude copper which is of over 94 % purity, is sent to the Niihama smelting works to be refined, before sending it to market.

The Niihama smelting works erected in 1883–1885 and improved later, has water-jacket furnaces and is doing an extensive work in the following manner:—

I.—Roasting. Roasting is done after a system pursued in this mine from ancient times.

II.—Smelting. A conical water-jacket furnace 13 feet high and with sixteen tuyeres, each 0.3 feet internal diameter, is used. This furnace measures 6×3 feet at the tuyere level. It works 60 tons of roasted ore in 24 hours and yields a matte containing about 40 % of copper.

III.—Roasting of the matte.—The matte is treated by the Star roasting process. The furnace used is 120 feet long and 22 feet wide with sixteen compartments, eight on each side of the central chimney from which the smoke from each compartment passes out. In each compartment wood is placed and upon this 15 tons of the matte are heaped. This matte roasting process takes about two weeks' time.

IV.—Smelting of the roasted matte. The furnace used is of the water-jacket type with a crucible in front in which the fused matte accumulates. It is round and measures 3 feet internal diameter and 10 feet high. The tuyeres are each 2.5 inches in internal diameter. About 30 tons of matte are fused per 24 hours. When the crucible becomes filled with molten matte, strong blasts are given to remove sulphur by oxidation, thereby enriching the matte until it contain 70 % of copper.

V.—Preparation of crude copper. A reverberatory furnace of an oval shape in the interior, 10 feet from the fire bridge to the top, 10 feet long and 100 feet wide, is here used. The charge 6 to 6½ tons takes 10 hours for being converted into crude copper of about 94 % purity.

VI.—Refining. A furnace of the same type as above is used. In 24 hours a charge of 7 to 7½ tons of crude copper is refined, to upwards of 99 % purity. The refined material is cast into ingots.

At Niihama, iron for used in precipitation establishments, and wrought iron is manufactured from the refuse left after the copper

has been precipitated. The refuse is first roasted to get rid of the sulphur it contains and made into brick-like lumps. These lumps are dried, fused in square furnaces, and manufactured into pig iron.

The manufacture of copper by the wet way is carried on both at Besshi and Yamane. The ore used is what is locally termed *megoma*, *yomogi*, or *iya*, a kind of cupriferous iron sulphide extracted together with the copper ore at Besshi. The annual produce of this ore is over 3,000,000 *kwamme*. It was not worked until about 1875, when the precipitation process was first applied to it. Wet process works have since been erected at Kadono and Takahashi, at the former in 1888 and at the latter a few years later. There are objections to enlarging this kind of work, which is now conducted as follows :—

I.—Ores 1 or 2 inches large are introduced into brick chambers measuring about 3 feet each way. The ore burns itself without any fuel. The sulphur fumes produced are conducted into a lead chamber, where they are converted into dilute sulphuric acid. The acid is afterwards concentrated in leaden boilers and sold as "brown sulphuric acid."

II.—The ore deprived of the greater part of its sulphur is pulverized in a crushing mill, and then by roasting in a brick furnace, has the remaining sulphur removed. A suitable proportion of common salt is now added and after some time the whole mass is taken out, stirred, and allowed to cool.

III.—The roasted ore is thrown into a water tank through which steam is passed and in which stirring rods are made moved by an engine. The copper solution thus obtained is then worked for copper and the residue for iron.

IV.—In the copper solution pieces of cast iron are placed. Steam is passed through the solution to make it warm. When the copper has all precipitated upon the iron, it is removed and refined in reberberatory furnaces.

Improvements in Metallurgy:—The chief improvements in metallurgy introduced since 1876 are as follows:—

1876.—An establishment for introducing the precipitation process was erected at Besshi. This process has since been improved and it is now pursued on the large scale above descrived.

1877.—Blowing machines run by water power were set up in connection with smelting furnaces.

1883.—At Niihama smelting works were erected having steam engines and blowing machines connected with them. Various furnaces were experimented upon and the water-jacket proved to be the best.

1886.—The works were put on the present plan and the old smelting process was entirely dispensed with.

1891.—The iron works were started with a view to improve and enlarge them in the future.

Percentage of Extraction:—The copper extracted usually amounts to about 7 % of the ore worked.

Expense of Smelting:—This is a little over 15.29 *yen* per 100 lbs. of fine copper.

Production Statistics:—The production of the last five years from 1887–1891 is shown in the following table:—

Year.	Copper.
1887	2,415,811 *kin.*
1888	2,907,794 "
1889	2,933,732 "
1890	3,376,233 "
1891	3,459,578 "

Supply of Fuel:—As the work has been gradually enlarged, the want of fire wood and charcoal has begun to be felt a little. This will not, however, prove a great difficulty as coke is now gradually superseding these fuels.

Power:—13 boilers—154 horse-power in all.
5 water-wheels—64 „ „ „

Transportation:—Transportation underground was formerly only on men's shoulders, but now in consequence of the progress made in the sinking of the shaft, from No. 1 to No. 6 level, it is done by means of a steam winding engine.

On the surface the transportation of raw or roasted ores and other things is done by light railroads and other mechanical contrivances, using the least possible amount of manual labor.

From the Besshi mine to Nagao, Tachikawa-yama, Nii-gori there is a tunnel in which a double-line railway is built. The crude copper, ores, and other things are carried on the railway from Besshi to the blast-furnaces at Niihama in horse or hand wagons.

From Nagao to Tachikawa (a distance of some 17 miles) in 1876 a new road was made, upon which things used to be transported on horse or ox wagons. This was lately found inadequate on account of the rapid progress achieved in the mining and metallurgical departments. Hence the following engineering works were found necessary:—

1.—The construction of a wire-rope tramway between Ishigasanjo and Hashideba, both of which are in Tachikawa.

2.—The building of a railroad between Hashideba and Sōkai, a distance of 6½ miles, started May, 1891, and completed July, 1892.

3.—The construction of a railway between Nagao and Ishigasanjo not yet completed.

From Niihama to the Sumitomo branch office at Kobe, all the manufactured copper used to be carried in Japanese junks, but of late

the managers have had steamers built for the express purpose of taking the copper to Onomichi in Bingo, there to transfer it into cars of the Sanyō Railroad Company. This is done when it is desired to have it at Kobe in a short space of time.

Markets :—All the copper the mine produces is first sent to the Sumitomo office at Kobe. Its principal markets are England, America, Hongkong, Shanghai, and British India.

ARAKAWA COPPER MINE.

Situation :—The Arakawa copper mine is situated in the village of Arakawa, Senpoku-gori, Ugo province, about seven miles from the high-way leading to Akita, the principal town in the province of Ugo; it is about twenty four miles south east from Akita and about three hundred and twenty miles north-east from Tokyo.

General History:—This mine was discovered in 1698 by a merchant of Akita named Kawamura Shōzaemon and was known by the name of Ugaizawa. Since then the mine has undergone various vicissitudes under many speculators among whom Kurosawa and Marquis Satake were the best known. In 1871 Mononobe Nagayuki reopened the mine, but as the modern method of mining was not understood at that time, he was soon obliged to stop the work. After the transfer of ownership to Okada Heizō, and Ono Zensuke, it came into the possession of the Government Mining Bureau in 1874. After two years it was sold to Segawa Yasugorō, the present owner of the mine, who after 17 years of hard work brought it to such a state of perfection that it now ranks among the foremost of the celebrated copper mines in Japan. How great the improvement is, may be inferred from the fact that while it had only 29 families and 67 inhabitants under the Government management, it now contains more than 640 families and over 4,000 inhabitants.

Geological Formation :—The geological formation is Tertiary and the rocks which contain the veins are shale, tuff, and brecciated tuff. In the Ugaizawa level there is a bed of augite propylite but it is not found on the surface. It is supposed that it was formed during the Tertiary Period because the veins are found to traverse it. Lipa-

rites on the north of Ushizawa and Matazawa are mixed with tuff, and are of great extent but have not yet been found underground. Dacites are found on the surface from Hirusawa to San-no-taki and have a peculiar columnar appearance and seem to have been formed after the Tertiary.

Ore Deposits:—There are many workable veins and they are all parallel to each other. Strike N 30° E, dip north east 60°–75°. One of the principal veins is called Ugaizawa Ohi, and is probably the best vein in the mine. It is said that more than half the productions uptill now has been from this vein. It is not less than 3,500 feet in length, and it varies from 1 feet to 25 feet in width of which one third is generally filled with ore. The Hiakume vein distant 1,600 feet from the Ugai-zawa vein is celebrated for its production of native copper. In Hikage-zawa there are two other veins which are called Mayebi and Tōbei. They are parallel to each other and the distance between them is not very great (about 160 feet). They are worked with the Samata level which reaches the front vein, Mayebi, at a distance of about 500 feet. It is 3 to 4 feet wide. The Tōbei is larger than the Mayebi vein, and they have produced a great deal of ore. Other important veins are as follows:—

Kanayama-zawa,
Yuno-sawa,
Nino-taki,
Omote-saka,
Miojin,
Katama-zawa,
Okuhi,
Tomeno-hi,
Azuki-zawa,
Hatzu-ishi, etc.

Quality of Ore:—The ores in the veins are generally very rich with chalcopyrite, and frequently native copper, cuprite, iron pyrites,

quartz, and barites and sometimes galena and sphalerite are found in the veins. The rich veins contain on an average 18–24 % while the poor 3 % of copper.

Levels:—All the mines are worked with levels. In Ugaizawa alone there are eleven levels and two adits for draining, of which the Chiugiri level is 887 feet and Ichi-no-taki Ogiri 2615 feet long. The highest level No. 7, is 500 feet above the Ogiri. All the main levels are laid with rails. It is proposed to sink a main shaft.

The Position of Smelting Works:—The smelting works are located in Ugaizawa on the bank of the Arakawa river, close to the mines. All the levels are situated on both sides of the river, stamps, concentrating works, roasting, smelting and refining furnaces, are built in proper order along the bank.

The Old Metallurgy:—All the ores from the mines were crushed by hand with hammers, and were washed and concentrated by means of baskets; the slimes were further dressed by means of round concave wooden pans, *yuri-ita*. The ore thus dressed, with a certain quantity of clay added was introduced into the roasting pit, and roasted for over ten days. It was then subjected to the smelting in a small hearth. The above mentioned old Japanese smelting and concentrating works were found to be expensive, and about six years ago some improvements were made.

The Present Metallurgy:—The following method is carried on at present: The ores are divided into two kinds by means of sieves:—

1st. The lump ore.
2nd. The fine ore.

1st. The lump ore:—The lumps after being washed are sorted by hand picking into first, second and third class ores.

a. The first class ores—to be roasted without dressing.
b. The second class ores—to be crushed.
c. The third class ores—to be stamped.

2nd. The fine ore:—The coarse portions of the fine ores are further concentrated by jiggers and handtables and the slimy ores by buddles. The ores thus dressed contain twelve to eighteen per cent of copper. They are roasted in two ways:—The fine ore and the first class lump ores are roasted by roasting furnaces and the ore from jiggers, by reverberatory furnaces. The roasted ores, with some matte, are then smelted in hearth furnaces to obtain a matte containing about 63 % of copper, and black copper containing 93 %. The matte thus produced is again smelted, in the hearth furnace together with ore, while the black copper is refined in another hearth furnace to get rid of impurities. The melted copper is then moulded into ingots. The copper thus prepared contains over 97.5 % of the pure metal.

The Percentage of Smelting Extraction:—It is said that eighty or eighty-five per cent of copper contained in the dressed ore is extracted by the smelting work.

Production Statistics:—The annual production of copper is 1,773,131 lbs. (1891).

The Fuel:—The annual consumption of fire wood and charcoal (1891) is as follows:—

Fire wood............ 3,327 cords or 425,800 cub. ft.

Charcoal .... 8,807,192 lbs. = (1,100,898,100 *kwamme*).

Mining Expenses:—The annual expense for mining amounts to 100,130.035 *yen* in 1891.

Smelting Expenses:—The annual expense of the dressing and smelting works amounts to 85,739.762 *yen* (1891).

Use of Water Power:—There are natural advantages for utilizing water power and therefore no steam power has ever been

used. All the power wanted for ore dressing, stamping, the mechanical shop, and other purposes has been supplied by water wheels only.

Transportation :—Both underground and surface transportation are very convenient. The ores and rubbish from the lower part of the mine are hoisted by hand winches, and those from the upper part dropped by a shoot, to the main level. Here there are rails and then it is carried out on wagons or carts. The surface transportation is carried on by means of the same wagons drawn by either men or horses. The copper is transported to market as follows. The copper product is first transported to Yodogawa, about eight miles from the mine, by horse back or in wagons. From Yodogawa to Tsuchizaki harbour distant about 30 miles, by small river junks. From Tsuchizaki it is transported to Yokohama viâ Hakodate in steamers.

Kakudate, commercial town,	about	11	miles	from	the mine.
Omagari do.	,,	24	,,	,,	,,
Akita, local government,	,,	24	,,	,,	,,
Tsuchizaki, sea port town,	,,	30	,,	,,	,,

OMODANI COPPER MINE.

Situation:—The Omodani mine is at Omodani in Kami-Anama Village, Ono-gōri, Fukui Prefecture, about 48 miles south-east of the town of Fukui, some 360 miles north-west of Tokyo and about 166 miles north-east of Osaka. It is in the eastern corner of the province of Echizen on the boundary line between it and Mino, elevated about 2,500 feet above the sea-level and almost completely surrounded by lofty mountain, there being only a small opening toward the north-west which leads to a narrow ravine below. Being thus situated, communication with the outside world is often cut off, especially in snowy and stormy seasons.

General History:—This mine was accidentally discovered by a hunter some five hundred and fifty years ago. At first the ores were taken to what is now Mochiana village about 2 miles from the mine and there smelted. The business only lasted a short period of time, not to be revived till a hundred years later. At its revival prosperity was enjoyed and a tide of emigrants flowed in. Since then it has experienced different turns of fortune under many different lessees. Some 60 years ago it came under Lord Doi, the feudal lord of the district, and it was pretty well systematized, Its later history is as follows:—

In the first year of the Restoration (1868), Lord Doi bestowed the mine upon the inhabitants of Omodani village,

1881.—The Omodani people were poor and therefore entered into a copartnership with a merchant of Akita. They were not very prosperous days.

January, 1888.—The present lessees (Mitsubishi-sha) had the mine transferred to them, and terms were agreed upon with the corporate body above mentioned.

Geological Formations, Ore Deposits and Quality of Ores :—The country rocks are quartz porphyry and in some cases sandstone belonging to Mesozoic Era. There are some faults coursing north 50°–70° west. These cut across the veins and change their position. The ore deposits strike north 30°–60° east. The main lodes dip 50°–80° north-west and the branch ones, 60°–70° south-east. There are ten of them, but none are more than 3 or 4 feet in breadth. Narrow lodes are often mined, as they yield rich ores The lodes chiefly worked are the Yobandate, Tachima, Buaibiki, Aoishi, Yosuke, etc.

The chief ore is copper pyrites. Erubescite, tetrahedrite and bornite are often found with the above ores, and they are generally argentiferous. The erubescite has often thin films of native silver upon it. Though sometimes containing zinc-blende arsenical iron pyrites and other minerals, it is on the whole remarkably free from admixtures.

Shafts and Levels :—This mine is worked not by shafts, but by adit levels.

The principal adits are the Ousagi and Nakagiri, the former about 120 feet directly under the latter. They measure as follows:—

Adit.	Main line.	Total length.
Ousagi	2,500 feet.	8,500 feet.
Nakagiri	2,000 „	5,000 „

At present two more levels are being opened, one called the Chūkōdo about 90 feet directly under the Ousagi and the other the drainage level nearly 150 feet beneath the Chūkōdo. The former has been excavated 650 feet and the latter about 1,200 feet.

Cost of Mining :—The raw ore 6 *yen* per ton and the dressed ore about 12.50 *yen*. The latter weighs half as much as the original ore.

Position of the Mill:—The mill where only black copper is prepared is at the pit-mouth. Refining and desilverization are done at the refining works in the town of Ono, nearly 27 miles from the mine.

Metallurgy known prior to the Restoration:—The metallurgical processes here pursued were similar to those followed at other copper mines in this country, only differing in the fact that they including desilverization. These were:—

I.—Ore dressed to about ½ inch size were thrown into a hearth made of mixed charcoal powder and clay, 1.2 feet in diameter and 0.8 feet deep and fused to obtain raw matte. The blowing apparatus was hand-bellows. A charge was 120 *kwamme*.

II.—The raw matte was fused, 150 to 200 *kwamme* a charge, in an eliptical hearth of clay and powdered charcoal, 3 feet in its long diameter, 2 feet in its short in diameter and 0.4 feet deep, to obtain No. 2 matte and bottom copper.

III.—No. 2 matte was smelted (in charges of about 120 *kwamme*) in a hearth 1.4 feet in diameter and 1.2 feet deep to obtain No. 3 or refined matte and bottom copper.

IV.—A similar hearth as in III. was used to convert No. 3 matte into crude or black copper. The charge was some 80 *kwamme* of the matte.

V.—The bottom and crude copper was mixed with about one-third as much lead to prepare copper-lead alloy.

VI.—The alloy was subjected to the usual liquating process. One workman could manage 13.5 *kwamme* of alloy per day. The remaining lead was next worked for silver by the usual method of cupellation.

VII.—Crude copper was refined. One man could work 100 *kwamme* of liquated copper.

Metallurgy after the Restoration:—This is much different from that above described, only the fresh ore is first roasted before smelting and the charges for the smelting furnaces are increased.

Improvements in Metallurgy:—It is not long since the present lessees have managed the mine and consequently nothing great has yet been achieved in the way of improvement. The following, however, have reduced certain expense:

1. Introduction of Baker's Blowers with Pelton water-wheels.
2. Enlargement of hearths.
3. The consequent reduction of fuel and labor required.

Fuel:—Wood and charcoal are abundant in this neighborhood. By the time the projected road repairs are completed, the lessees will have no more difficulty as to fuel.

Production Statistics:—

In the year, 1890.		
Ore	6,490	tons.
Black copper	365	„
In the year, 1801.		
Ore	7,660	tons.
Black copper	404	„

When the present lessees get more experience, they may gain more. The yield of this year looks like being about equal to that of the last. About one-third of the black copper is now refined, the rest being sold unworked. It is hoped in the near future, to have all the black copper refined, before sending it to market.

Percentage of Extraction:—Nothing certain can be said upon this point, as the metallurgical processes are yet being improved. The slags from the old works are now stored, but what percentage of metal they yield no one yet knows. As now worked the ores yield 60 to 70 % of copper.

Cost of Metallurgical Work:—The cost of working 1 ton of dressed ores is:—

Wages	1.90 *yen.*
Fuel and other necessaries	6.60 „
Miscellaneous	0.70 „
	9.20 *yen.*

Markets :—The product is all sent to Osaka viâ Tsuruga, Gifu, or Yokkaichi. High rates are consequently paid on account the inconvenient position of the mine. Except in stormy seasons the rate for 100 Japanese pounds is 60 to 70 *sen* by any one of the three roads above mentioned.

Remark :—In conclusion we may mention that the copper from this mine, is superior to any produced in the numerous copper mines of our country. It is best for fine copper-work and for making fine wires and thin plates. At our Army Arsenal no copper other than that from this mine is used for making important copper pieces in various arms.

Transportation :—

1. Underground.

On slopes	Winding wheels.
In levels	Wagons on rails.
To slopes or levels	Barrows or men's shoulders.

2. Outside.

On repaired roads	Hand, horse, or ox wagons.
Mostly	Men, horses, and oxen.

Power :—Two Pelton waterwheels of American make, one 3 feet in diameter and the other 5 feet, are used. The former operates upon 1 No. 2 Baker's blower, 1 fan, and 1 stamping mill for pulverizing charcoal and is thought to have force enough to move a Frue vanner besides. The latter acts upon 1 Dodge crusher, and 2 three feet and a half Huntington mills, and it is projected to have it further operate upon 1 drum, 2 jiggers, and 1 lathe.

KUSAKURA COPPER MINE.

Situation:—The Kusakura copper mine is the general appellation of the Kusa-kura, Funa-uchi-zawa, Nameri-daki, Shina-ga-yatsu, Naka-iwa-zawa, and Kuro-zaki Kita-hira mines, all situated at Kanose, in Morogase village, Higashi-Kambara-gōri, Yechigo Province, Niigata Prefecture.

General History:—There exists no authentic record relating to the discovery of this mine, but tradition says that the first notice of it was the discovery of ore exposures in a dale named Sankaku-zawa by Mozaemon, Sashirō, and Kimpachi from the town of Tsugawa. Of its history nothing certain is known before it was leased to Furukawa Ichibei in 1876. It is, however, popularly believed that one Kusaka Dembei of Morogase village worked it from somewhere between 1772 and 1780 to somewhere between 1804 and 1810, and that it then came under the management of the feudal lord of Aizu and showed a considerable degree of prosperity between 1827 and 1852, producing 58 tons (97,000 *kin*) of copper per year and giving employment to some three hundred miners.

In December 1876, Furukawa Ichibei had the claim transferred to him. For the first few years of his management, the annual production of copper was 30 to 35 tons (50,000 to 60,000 *kin*), but in 1883 it suddenly rose above 1,000 tons (1,700,000 *kin*). This was the greatest yield the mine ever saw and it still continues.

Geological Formation:—The rocks enclosing the ore deposits are volcanic rocks of the eocene and pliocene series. The eocene rocks are stratified tuff with which calcareous sandstone, conglomerate and shale are seen ranging in successive strata.

The pliocene ones are calcareous sandstone, calcareous clay, conglomerate and tuff. These two sorts of rocks are nearly alike in properties, only the former are harder and contain more tuff than the latter, which contains much calcareous clay.

Ore Deposits:—There are four veins called the Kusakura, Funauchi-zawa, Nameri-zawa, and Naka-iwa-zawa veins. The first courses from the north-east to the south-west, dips westward or nearly vertical, and is about 3,000 feet long and 1 to 4 feet wide. The second, 1800 feet distant from the first, courses and dips nearly like the first. It is 1,200 feet long, and ½ to 6 feet wide. The third, extending from the north to the south, dips westward some eighty degrees. It is 1,200 feet long, by 1 to 3 or 4 feet wide. The fourth, coursing from the south-west to the north-east and dipping some ten degrees west-ward, is 900 feet long by ½ to over 5 feet wide.

In general character these veins are nearly alike. Their gangues are of quartz, and are all very hard. Eight clay veins, each varying in size, run across the Kusakura and Funauchi-zawa lodes. These cross-courses, striking from the west to the east and inclining some eighty degrees, are distant one from another 50 to 600 feet.

Quality of Ores:—The ores are rather rich and the yield of copper averaging 25 % of dressed ores. The chief ores are chalcopyrite and covelline. Iron pyrites native copper and bornite are sometimes found with them.

Levels and Shafts:—There are two shafts, each 750 feet deep, subserving the purposes of transportation and ventilation.

The total length of the levels is about 21,000 feet. The longest of them is 7,500 feet.

The longest railroad running in the levels is 7,500 feet and their total length, 13,500 feet.

Cost of Mining:—The cost of mining 100 *kwamme* of dressed ores is 12.508 *yen* as shown below:—

Wages of miners................................	1.064 *yen*.
Transportation in pit	1.592 „
Materials consumed	.276 „
	12.508 *yen*.

Position of the Smelting Works:—The smelting works are on the bank of Akanogawa, a navigable river at Tsunokami, in Morogase village. It is so conveniently situated that all the products can be shipped directly to junks.

Metallurgy Introduced after the Restoration:—

Roasting:—From 1877 to June 1882 ore was roasted in a round pit dug in the ground, 3.5 feet deep and 5 feet diameter and with an opening at the bottom for the current of air and having its walls thickly plastered with clay. Three hundred *kwamme* of ore and one *tana* of wood (2 feet long × 5 feet wide × 5 feet high) were put into it in alternate layers of proper thicknesses. It took four weeks to roast completely. In July 1882, an ordinary reverberatory furnace 148.5 feet long, 11 feet wide and 5.7 feet hight and having fifteen chambers, was erected. The charge of 180 *kwamme* is thrown into the first chamber and is hourly sent onward into the chamber beyond. Fifteen hours are thus required for the complete roasting of a charge, this furnace roasts 4320 *kwamme* of ore per 24 hours, employing twenty laborers and consuming seven *tana* of fire wood.

Smelting:—In 1877 smelting was performed in a pit. This pit had its sides covered with stones, which were coated with a mixture of powdered charcoal and moistened clay. The longer sides of the hearth each measured 3.8 feet, and of the shorter, the front one, 2.5 feet and the rear, a little less than 2 feet. In depth it was about 3.7 feet. Before smelting was begun in this hearth, it was customary to heat it a little keeping its mouth partly closed for the while with clay. After that 300 *kwamme* of ore were thrown into it in two

equal parts and smelted, using two box-bellows each five feet long. In 1878 the box-bellows were abandoned and leather ones introduced, thereby doubling the quantity of ore smelted at a time. Seven years later, a No. 4 blowing machine run by an 8 horse-power boiler made to force the air into eight hearths at a time, came to be used instead of the leather bellows. This machine acted so well as to increase the quantity of ore smelted in one hearth at a time to 900 *kwamme*. In September 1890, the imperfect Japanese hearths were abandoned, an improved water-jacket furnace was erected. This furnace is still used and the charge it receives consists of:—

Ordinary ore	75	*kwamme*.
Matte	15 to 20	,,
Fine ore (powder)	10	,,
Slag	20	,,
Lime	12	,,
Charcoal	22	,,

It is used seven times in 24 hours, giving work to eighteen laborers, and smelts;—

Ordinary ore	5,250	*kwamme*.
Matte	1,050	,,
Slag	1,400	,,
Fine ore (powder)	700	,,

In its use, the blast being found rather too weak, the 30 horse-power boiler before placed in the adit level for use in running dressing apparatus was in October 1891 taken to the smelting work. It is now used for running the blowing machine and dressing apparatus.

The Precipitation or Wet Process:—The material treated by this process is the contents of the slime-pits, which receive the tailings from Duncan concentrators and buddles. The slime contains some 3 % of copper. Formerly this was roasted in ground hearths and smelted in the same manner as ordinary ores, but a considerable loss was inevitable from its extreme fineness. It was in Dec. 1890

that this process was adopted and since then it has yielded about 650 *kwamme* of copper every month. It is being improved but as practised at present it is as follows:

Roasting is done in the same manner as already stated. The roasted ore is treated on fine sieves and the coarser portion is pulverized in rolls. The ore thus prepared is put into a wide-mouthed vessel in connection with which there are two boxes for warm water *A*, eight so-called reserve pails *B*, eighty pails for slime *C*, and nineteen pails in which copper is made to precipitate *D*, arranged one lower than another. *A* receive the warm water pumped out from the tank attached to the water jacket which is made to flow out into the pails below. *B* contains the diluted liquid from which copper was once separated. This liquid together with the water in *A* is made to flow down into *C* through filters. In *C* there are iron filings on which the copper precipitates. The wide-mouthed vessel above referred to (5.5 feet diameter and 2.2 feet deep) receives 200 *kwamme* of slime, which it takes twenty to twenty-five days to work by this process. In *C* about 200 *kwamme* of iron filings are put in at first. These are raised, washed, and have the copper, which has precipitated on them, taken off once in thirty days. The cement copper thus precipitated contains some 80 % of copper. This is sent to the water-jacket and smelted. It is estimated that the reduction of iron is 80 *kwamme* for every 100 *kwamme* of copper.

The above process, treating such materials as are impossible to work profitably by ordinary methods, is not at all expensive and it is consequently practiced with great profit.

Consumption of Fuel and Lime:—The lime, wood, and charcoal used per year are respectively 250,000 *kwamme*, 9,500 *tana*, and 750,000 *kwamme*, on an average.

Production Statistics:—The production of copper from 1877 to May 1892 is 15,677,576,175 *kin* (100 *kin* of copper = 16 *kwamme* of it) as shown below:—

1877	155,371,371	*kin.*
1878	181,046,250	„
1879	287,436,750	„
1880	288,776,250	„
1881	305,858,500	„
1882	746,498,500	„
1883	1,718,396,250	„
1884	1,871,486,875	„
1885	1,787,778,125	„
1886	1,511,315,000	„
1887	1,623,540,250	„
1888	1,303,405,675	„
1889	1,323,500,500	„
1890	1,179,409,000	„
1891	1,021,102,000	„
1892 (till May)	372,655,000	„

Cost of Smelting:—It is 2.47 *yen* per 100 *kwamme* of ore as detailed below :—

Roasting	.61	*yen.*
Smelting	1.87	„
	2.48	*yen.*

Use of Steam Power :—A 30 horse-power Root's boiler is used with dressing and metallurgical appliances.

No water power is employed.

Transportation :—The levels have railways constructed in most places, but where they are very narrow or run very ziggag, transportation is on men's shoulders. The shafts have winches provided. Outside the mine men, cattle, and wagons are used, no railroad has yet been built.

There are twenty junks constantly running on the Akanogawa river specially for taking copper from and various necessaries to the mine.

Distances to Markets:—

To Tsugawa	5	miles.
„ Shibata	20	„
„ Wakamatsu	43	„
„ Niigata	41	„

OGOYA COPPER MINE.

Situation :—The Ogoya Copper Mine is in the district of Ogoya, Nishio-mura, Nomi-gōri, Koga Province, Ishi-kawa Prefecture, about fifteen miles from the shores of the Japan Sea and 35 miles south west from Kanazawa.

It is on the Okurayama, a branch peak of the Hakusan range near the source of the river Satoya-gawa.

The claim is said to be over 800,000 *tsubo* in area. The mine is worked with several levels. The lowest drainage level is eight hundred feet above the sea.

General History :—It is quite a new mine discovered after the Restoration (1868) by some peasants living in the neighbourhood of the mine. Two miners Tachibana Sahei and Murata Jinyemon found the Matzu-ga-midzo outcrop while gathering mushrooms.

A farmer of Ogoya village worked it after the discovery; but shortly after gave it to Yoshida, who finding it poor and unprofitable, sold it to Yokoyama Riuhei, the present owner. He did much in prospecting and also greatly improved all the workings. The investments proved to be a complete success.

In March 1881 he found the best vein which is working at present. All the levels have been opened and various other improvements have been made. The result has been an increased production of copper in a few years.

This year the lower drainage, and other new adit levels, and shafts, have been opened while new machines, dressing and smelting works have been biult. By the meanes the scale of working has been increased.

Geological Formation :—The country rocks near the mine are entirely of gray tuff quartz andesite and quartz trachyte; belonging to Tertiary; colour reddish brown; strike north 10°–20° N.W. The hardness and density of these rocks vary in different places. No fault is found in this mine except in the Kanayama-dani mine in the village of Ate-mura

Ore Deposits :—The ore deposits are in the form of veins, which are almost parallel to each other. There are many veins on both sides of the river. The main vein on the north side of the river strikes N. 65° W. and dips 70°–90° N.E. or sometimes S.W. 2–3 inches to four feet. On an average it is not less than 8–9 inches. Some other two or three small veins are parallel. Very often they meet together. They are said as a rule in this mine, to be very rich when the dip of vein is gentle.

The veins are from 500 feet to 2,000 feet long. On the south side of the river there is a workable vein which has a strike N. 60° W. and dips 80° S.W. To the west of this vein there are two veins which strike N. 30° W. and dip 40°–60° S.W. Their thickness is about one foot. The veins at the Ate mine may perhaps be the same as those at the Ogoya mine.

Quality of Ores :—Ores from all the veins are very rich. The gangue is chiefly of quartz, but sometimes it consists of broken parts of the containing rock.

The ores are of various kinds, such as, chalcopyrite, tenorite, bromite, covelline, native copper, galena, and iron pyrites. Sometimes very fine crystals of iron pyrites are found in the veins, but no other foreign minerals, therefore, the copper is of a very pure quality. The ores are assorted into two classes.

1—Ore containing 25–26 % of the metal does not need dressing before subjecting it to the smelting process.

2—Ore containing 4–5 % needs to be dressed in order to raise it to 15–16 %.

Shafts and levels :—The mines are worked with levels and underground shafts. The levels are of very large size, and they are laid with rails. The shaft in the main level was sunk along the vein. It is 210 feet deep. It measures 6 × 15 feet excluding the frame. It is divided into three compartments; two of which are used for hauling, and the other is subdivided into two parts, one of which is for ladders.

Besides this there are several winzes 4 × 8 feet connecting various levels, and each of them is provided with a windlass. There are many levels worked at present, of which the principal are as follows :—

		The length of the levels.	
In the main adit	Tamadare	988 ft.	Of which the first is situated highest and so on in order.
	Yeikichi-date	1,310 „	
	Naka-date	890 „	
	No. 1 Level	2,174 „	
	„ 2 „	1,475 „	
	„ 3 „	380 „	
Semado level		1,257 „	
Omizo „		590 „	
Nakamizo „		926 „	
Otamizo „		887 „	
Kanayama-dani level		870 „	
Takanari		1,543 „	

Mining Expenses :—Ores are obtained from the miners by purchasing. They are divided into three classes according to the quality of ores. Ore is purchased at the following rates :—

Ore.	Per 100 *kwamme*.
Ore containing over 60 % Copper	3.10 *yen*.
„ „ „ 20 % „	2.30 „
„ „ under 20 % „	1.50 „

The monthly production of ore amounts to 47,000 *kwamme* in dressed ore which costs the owner 3,814.99 *yen* *i. e.* 6.693 *yen* per 100 *kwamme*.

Position of the Smelting Works:—The smelting works are in front of the main level, and a quarter of a mile from the mouth of every level, except the Kanayama-dani, which is about two miles away. The dressing works are near the roasting and smelting furnaces, where the work is performed by water power. Although this is the most economical method it is yet a source of no little difficulty and inconvenience.

The Metallurgical Processes:—The smelting process at this mine is an ancient one called *Yamashita-buki*, which consists in first roasting and smelting the ore for the production of matte, and then again roasting and smelting the matte for black copper. The following are the details of the smelting work:—

1—Ore roasting.
2—Ore smelting.
3—Matte roasting.
4—Matte smelting.

1. Ore Roasting:—Ore is roasted to eliminate a part of the sulphur.

Ore subjected to roasting is of three sorts:

a. Lump—about 0.1 feet cube.
b. Small—0.004–0.05 feet cube.
c. Grains—Finer than 0.004 feet cube.

The lump sort (*a*) is roasted in a elliptical pit (Japanese roasting furnace) 7 feet wide, 10 feet long and 5½ feet deep.

A charge is 4,300 *kwamme*, and the fuel consumed is proportionally 300 *kwamme* of wood per 500 *kwamme* of ore, the first three layers of wood are respectively about 0.07 feet, 0.15 feet and over 0.45 feet in diameter. On the wood ore is thrown. Then the wood is kindled at the fire place.

Ten to fifteen days are required for complete roasting.

The small sort (*b*) is roasted in a eliptical or circular pit in exactly the same manner as above mentioned, a charge being 900 to 1,700 *kwamme*. The wood consumed is at the rate of 50 *kwamme* per 100 *kwamme* of ore and 16 to 22 days are required to complete an operation according to the size of the pit.

The grain sort (*c*) together with the precipitate and dusty products are first moulded into blocks, and then roasted in the eliptical or circular pit at the rate of 300 to 1,500 *kwamme* a charge. The wood consumed is 55 *kwamme* per 100 *kwamme* of ore, and 13 to 33 days are required for the roasting.

2. Ore Smelting:—One charge of smelting work is 600 *kwamme* in winter, and 400 *kwamme* in summer.

The 400 *kwamme* charge of the roasted ore consists as follows :—

Roasted lump ore	215 *kwamme*.
„ moulded ore	147 „
„ slag	38 „
	400 *kwamme*.

As it takes seven hours for one charge, three charges are performed during one day. The charcoal consumed in one charge is on an average 82 *kwamme*.

The production from one charge is 13 *kwamme* of copper, 87 *kwamme* of matte and a certain quantity of slags. The above process is conducted after the *Yamashita-buki* with leather bellows.

3. Matte Roasting:—The matte is again roasted both in the larger (6.5 feet wide, 9.5 feet long, and 4 feet deep), and in the smaller kiln (circular shape 5 feet diam. and 4 feet deep). The former can take 1,200 *kwamme* at one charge and the latter 210 *kwamme*.

The wood consumed is 400 *kwamme* per 10 *kwamme* of matte.

The processes are the same as in the ore roasting, only no wood larger than 0.35 feet diam. is used in this case. 7 to 14 days are required for completing one charge.

4. Matte Smelting:—One charge of matte is 400 *kwamme* and it takes 7 hours to smelt. This yields about 174 *kwamme* of

matte 113 *kwamme* of black copper and a certain quantity of slags. The matte thus produced is repeated as in (3) matte roasting.

The reduced copper is ladled out and cast into iron moulds, and after being solidified, it is thrown into water and cooled. This product is black copper.

Improvements in Metallurgy:—The old smelting process is mentioned above, but at present some improvements have taken place, such as the old concentrating basket used in hand dressing, has been replaced by trommels, jiggers, buddles, etc. worked by water power, and blowing machines have been substituted the old box-bellows.

Other improvements going on, in order to enlarge the scale are the rebuilding of new smelting, and dressing works, etc.

Percentage of Extraction:—This varies considerably with the different ores, but on an average over 55 % is extracted and a considerable loss occurs during the dressing.

Copper produced from 1880 to 1890.

Year.	Pound.	*Kwamme.*
1880	18,317	3,198,000
1881	50,392	6,047,000
1882	206,874	24,824,870
1883	373,548	44,825,800
1884	506,326	60,759,060
1885	569,255	68,310,649
1886	875,466	105,055,968
1887	1,151,682	138,201,800
1888	1,309,243	157,109,200
1889	1,509,998	181,197,340
1890	1,235,394	148,247,220
Total	9,105,561	1,092,667,327

CONSUMPTION OF FUEL FROM 1888 TO 1890.

		1888.	1889.	1890.
Hard charcoal	*Kwamme.*	299,453.00	343,625.40	344,703.96
Common charcoal...........	*Kwamme.*	76,881.50	76,417.60	82,412.50
Blacksmith's „	Bales.	4.071	7.036	7.999
Brushwood „	*Kwamme.*	375,981.10	730,840.58	1,052,433.50
Wood	Bundles.	69.337	60.983	64.216

Expenses of Working:—The cost of dressing and smelting 100 *kwamme* of dressed ore are as follows:—

Dressing expenses	0.966 *yen.*
Roasting and smelting	3.225 „
	4.191 *yen.*

Use of Steam and Water Power:—A 30 horse-power Cornish boiler is used at the pit mouth to make steam for an underground winding engine and pumps. Three water wheels 20 to 28 feet in diam. are employed for motive power in dressing ores, blowing machine and the work shop.

Transportation:—The main levels are laid with rails. The wagons are used to carry ores and rubbish. In the shaft by means of a winding engine and in the winzes hand winches are employed. On the surface a considerable length of tramway is laid, and a wire tramway is built from the Nakamidzo mine to the dressing works.

Distance to Markets:—The distance from the mine to markets are as follows:—

Komatsu	12 miles.	in Kaga.
Kanazawa.......................	31 „	in Kaga.
Adaka	14 „	in Kaga.
Tsuruga	90 „	in Yechizen.

The road running to Komatsu is not level but allows the passage of carts.

YOSHIOKA COPPER MINE.

Situation :—The Yoshioka mine is situated at Fukiya village, Kawakami-gōri, Bitchiū Province, Okayama Prefecture.

General History :—No authentic record exists as to when the mine was first opened, but tradition puts it at 807. For the next six hundred years nothing is known. The immense heaps of old slag lying about Ofuka, however, entitle us to say that there must have been extensive working during this unknown period.

For one hundred and sixty-four years preceding the years 1558 to 1569 the Middle Provinces of Japan were the scene of almost incessant wars and mining work had to lie idle. When peace was established Otsuka Magoichi and Matsuura Goemen resumed and enlarged the mine. It was these men who carried the mining work into the regions now known by the name of the Yoshioka mine. Before their time it had been limited to the Ofuka and Kitagata districts.

In the years 1573 to 1591 the property fell into the hands of Mōri, a feudal lord, but when Toyotomi came into power, it became his, and he held it for over twenty years. Two men named respectively, Kasuya Sukeëmon and Kasuya Sukebyoe were the managers employed by this famous hero.

Under the Tokugawa in 1616 it first became the property of Kobori Tōtōmi-no-Kami and two years later it fell into the hands of Yamazaki Kai-no-Kami who, after working it for nineteen years, transferred it to the Tokugawa Government. Unnder this government the first manager Ogawa Tōemon and his successors made many improvements and its condition was entirely changed. For nearly

a century from 1646 to 1742 the work seems to have been on quite a large scale; it was then that No. 1 adit level was first made for draining purposes.

The owners of the property after the Shōgunate Government were successively Itakura Suwō-no-Kami, the head of the Matsuyama clan and one Iiji of the Okayama clan. Under them the work was not discontinued, but it became less prosperous year by year, until 1873, when it was transferred to the Mitsubishi Company.

In 1881 a rock-drill was introduced and adit-levels were driven, levels repaired, and shafts sunk. Prospecting has since gone on quite extensively. The result is the present condition of the mine.

Geological Formations, Ore Deposits and Ores:—The oldest rocks of this mine are perhaps those exposed about Funashiki which are dark-green in color and capable of being split into leaves. They may belong to the crystalline gneiss system. East of these rocks in the neighbourhood of Ofuka there are strata of diabase together with clay-slate, sandstone and diabase tuff (which are extensively developed in this district), belonging to the Chichibu system of the Palæzoic group. Near No. 3 drainage level, there are two veins of porphyrite, at one place through the phyllite and at another through the Chichibu rocks.

The ore deposits are in the form of veins, of which the most important are the Funashiki, Daisen, Kishiyama, Senga, Gofukuyama, and Idzumishiki. On the whole they run east to west and dip 30 to 80 degrees northward. In breadth they are from one to eight feet.

The crude ore loses seventy per cent. by dressing. The dressed ore yields nine per cent. of metal.

The Site of the Smelting Works:—At present we have two smelting works, one at a considerable height and the other in a dale named Sakamoto Okiri Dani, below the drainage level. The latter, which is yet only half finished and doing only half work, has been building since last year. Its object is to supersede the former,

which is inconvenient in many respects, especially as regards transportation.

Dimensions of Shafts and Levels:—

Shafts.

From Funashiki to No. 2 Level	200 feet deep.
From No. 2 to Kawashita Level	115 „ „

Levels.

No. 2 Level	780 feet long.
No. 3 „	6,036 „ „
Kawashita Level................................	4,212 „ „
No. 4 „	7,026 „ „

Drainage Levels.

Daisen Level	960 „ „

Metallurgy:—The present metallurgy is a mixed system of old and new styles. Thus in the treatment of the coarser ores the old Japanese roasting hearth is used at the old mill and a peculiarly constructed one of the new style at the other, while the finer sorts are roasted in regular roasting furnaces. Of the roasted ore 1,000 *kwamme* are heated in a furnace for matte and the matte smelted 120 to 200 *kwamme* per hearth, the copper being cast into ingots. As to smelting, the present metallurgy is no further different from the old system than that it can treat two and a half times more ore in a furnace at a time. The matte contains 40 to 55 per cent of copper.

Percentage of Extraction:—The average is 95 per cent of copper contained in the ore.

Mining and Metallurgical Expenses:—The expenses per 100 *kwamme* of ore are as follows:—

Mining...	2.279 *yen.*
Metallurgy	2.813 „

Production Statistics:—The yearly produce of crude copper from 1875 to 1891 is as follows :—

1875	22,720,000	*kwamme.*
1876	30,933,818	„
1877	29,056,000	„
1878	20,808,000	„
1879	15,355,792	„
1880	13,789,580	„
1881	13,964,329	„
1882	15,136,480	„
1883	19,750,400	„
1884	35,015,000	„
1885	97,874,000	„
1886	91,849,694	„
1887	77,852,500	„
1888	96,434,890	„
1889	127,680,000	„
1890	160,073,100	„
1891	190,151,578	„
	1,058,945,161	*kwamme.*

The crude copper contains some 30 *momme* of silver per 16 *kwamme.*

Supply of Fuel:—The trees in this neighbourhood have mostly been consumed and the charcoal needed has to be brought from distances of from 17 to 29 miles. In the future prohibitive prices may be asked for it or even it may not be obtainable. In such a case coke may be used. At present it is possible to get it in any quantity and at a reasonable price.

Wood is also scarce in the neighbourhood and is supplied from places 5 to 10 miles distant. But, if roads be repaired in order to get it from distant places (strict regulations being established as to

felling the neighboring forests), no difficulty seems to lie in the way of having it sufficiently and economically supplied.

Power:—No steam or hydraulic power have ever been used.

Transportation:—Railways or wooden tramways are constructed both in and out of the pits. On the former, wagons each 200 *kwamme* capacity are used, and on the latter wagons of half size.

Distances to Markets:—The produce is all sold in Osaka, which is 151 miles from the mine. As Okayama 110 miles is connected with Osaka by railway, transportation is simple and convenient.

OSARUSAWA COPPER MINE.

Situation :—The Osarusawa copper mine is one of the largest and most celebrated mines in Japan. It is situated in the village of Osarusawa, Kazuno-gōri, Rikuchiū Province, Akita Prefecture. About 400 miles north-east of Tokyo.

General History :—There is no authentic record of its early history, but it is said that the gold in this mine, was discovered in or after the year 1600, and about 50 years later copper was discovered. Since their discovery which is more than 280 years ago, these mines have been constantly worked under different proprietors. It is said that, the mines were most productive during the five years from 1760–1774. From 1788–1791 they were less productive; but the output again increased in the years 1864–1878. Although in 1884 the product was small, at present it is as good as ever it was.

For the last few years all the mines have been owned by Mr. Iwasaki Yanosuke who also owns other mines like as the Okuzu gold mine and Komaki silver mine in the neighborhood.

Geological Formation :—The country rock that contains the mineral veins is of tertiary tuff.

The Ore Deposits :—They are in the form of veins. There are more than 25 veins and they are very rich in gold, galena, and copper pyrites.

The gold is principally contained in quartz close to the hanging and foot walls. The upper part of the veins are rich in gold, but it gradually decreases with depth. Sometimes gold ores are rich when

the copper ore fails. Below 300 feet from the surface gold ores entirely change to copper ores.

The rich copper ores are chiefly accompanied with blende and galena.

Quality of Ore :—The ores are very rich and gold, copper, and galena are contained as follows :—

Gold	0.004	%
Copper	10.000	„
Galena	50.000	„

Levels and Shafts :—There are many levels. At present seven levels are worked. Their lengths are 720 feet, 2,280 feet, 5,000 feet, 4,300 feet respectively. In addition there are 6,000 feet of branch levels. All of them are laid with rails. There are also six underground shafts which are about 75 feet to 110 feet deep. All provided with windlasses.

Mining Expenses :—The expense for mining amounted in 1891 to 63,500 *yen*.

Position of Metallurgical Works :—The dressing and smelting works are situated at Shishizawa close to the mines. They are in good order.

Old Metallurgy :—There are three metallurgical processes for gold, for copper, and for lead.

1. Gold ore: The gold ores are crushed by hand, into small lumps with hammers. These lumps are ground by mills and washed so as to separate the gold from the ores. The gold dust thus obtained is smelted with a certain quantity of lead, and the auriferous lead is subjected to cupellation.

2. Copper ore: The copper ores are first crushed into small lumps with hammers and then pulverized in mortars. The grains

thus obtained are washed and dressed in baskets by girls. They are subjected to roasting and smelting.

Calcination :—After dressing they are roasted in a rude furnace made of stone 10 feet long, 4 feet wide and 4 feet deep. The fuel is placed at the bottom of the furnace, and the ore is placed upon it and kindled. It takes about 20 days to complete the roasting, but the number of days required varies with the season.

Ore Smelting :—About two and half tons of the roasted ore is smelted per day in a hearth furnace built on the ground, 2 feet deep, 2 feet wide and 2½ feet long, to get the matte.

Matte Roasting and Smelting :—The matte thus obtained is again roasted and smelted for black copper.

3. Lead ore: The lead smelting is similar to that of copper smelting.

Improvements in Metallurgy :—For gold smelting there are no improvements. All the processes are carried on at present by the old methods, but in the metallurgy of copper some improvements have been made. They are as follows :—

1. Crushers for crushing ores.
2. Reverberatory furnaces for roasting powderly ores.
3. Hand jiggers for jigging ores.
4. Water jacket for smelting ores.

Fuel :—About 10,000,000 lbs. of fire wood, and nearly 708,333 lbs. of charcoal were consumed during the year 1891. Fire wood is easy to get but it is extremely difficult to obtain charcoal.

For saving the fuel a certain quantity of lime is added as a flux in the smelting of raw ores and it proves successful. Coke is now being experimented with as a substitute for charcoal.

Production :—The production in 1891 was as follows:—

Copper	1,000,000	lbs.
Gold	33.5	,,
Lead	30,000	,,

Percentage of Extraction :—The black copper is 10 % of dressed ore.

Smelting Expenses :—The annual expenses amount to the sum of 58,000 *yen*.

The Use of Steam Power :—An eight horse power boiler is used for working crushers.

Transportation :—For underground transportation the principal levels are laid with rails. On the surface, the principal transportation is on steep places by men and horses but on level places by wagons.

Distances to Market :—The mine is only about 2 miles from Hanawa, a commercial town in this district, where the County Office, Police Station, and District Court House are situated.

It is about 100 miles to Akita, on a good road and about 50 miles to Morioka, but the road is bad. At Morioka we connect with the Aomori and Tokyo line of railway.

KOMAKI COPPER MINE.

Situation:—The Komaki copper mine is situated on the north bank of the Yoneshiro river, close to the bouudary line between Kita-Akita-gōri in Ugo, and Kazuno-gōri in Rikuchiu.

General History:—Tradition states that the mine was first discovered about the year 1596, but no authentic record exists to prove it.

About the year 1771, it is said that the Nambu clan reopened the mine and a high pitch of prosperity was attained. The metal sought after, however, was gold and not copper as at present,—hence, probably, its old name of Shirane gold mine. A few years before and subsequent to the Restoration, it was almost idle. In 1880, what is locally, called *Doko* (earthy ore) was found cropping out on the top of Mt. Komaki. On prospecting this proved to be a silver deposit and accordingly in 1885 the Kiss process was practiced. For the three subsequent years the yield of silver was quite satisfactory, but after the deposit became narrower and the ores to be of lower grades in October 1890, working for the white precious metal was entirely given up. While digging for silver ore, copper deposits were found below, and after the former metal was abandoned these deposits were worked. It has been continued till to-day, though to no considerable extent.

In the meanwhile, in that part of the mine locally termed Mt. Shirane, old mines were opened, the lodes examined, and shafts sunk for obtaining gold and copper. As the former metal was only found in mere traces, copper alone could be profitably extracted. Thus it has turned out that to call this mine a copper one is nothing but a misnomer.

Geological Formation and Ore Deposits:—The rocks of this mine are Tertiary tuffs.

In the case of Mt. Komaki, the deposit courses north-east to south-west. It is 1,300 feet long, and 200 to 300 feet wide. In all probability it was formed by natural precipitation from a hot-spring. The copper veins underlying the silver deposit are small and irregular and run in several directions. Their width sometimes exceeds 2 feet.

Mt. Shirane has several irregular veins, running through the tuff, which meet and intersect one another. The more important of these veins are four in number, viz: The Nakahi, Mayehi, Mitsuai Mayehi, and Honkodo Mayehi. Each of them is 1 to 2 feet in width, and courses independently in directions between north-east and south-west occasionally intersecting one another. They dip southward at angles of 60°–70.° These veins are found to become shorter and narrower and the grade of ore worse as they are worked deeper, and thus their production seems to be limited.

Quality:—The ore is copper-pyrites. That from Shirane contains 5 %, and that from Komaki, 7 % of copper.

Depth of Shafts and Length of Levels:—

Mt. Shirane Mine.

The Main Shaft is 300 feet deep, and the winzes each 100 feet deep.

No. 1,	Level in first 100 ft.......	3,500 ft. long.
No. 2,	,, ,, second 200 ft. ...	4,000 ,, ,,
No. 3,	,, ,, third 300 ft.......	1,850 ,, ,,
No. 4,	,, ,, fourth 350 ft.	500 ,, ,,
No. 5,	,, ,, fifth 400 ft.	130 ,, ,,
		12,000 ft. long.

Mt. Komaki Mine.

Winze	150 ft. long.
Levels	3,000 ,, ,,
	3,150 ft. long.

Expense of Mining:—In 1891, the cost per 100 *kwamme* of ore was 84 *sen*.

Position of the Metallurgical Works:—The metallurgical works are situated adjacent to the mine on a hill near the Yoneshiro River.

Metallurgy:—Prior to the Restoration (1868) gold alone was extracted by using stone mills, and rude forms of concentrators and classifiers. Lately proper processes have been introduced. The present copper smelting is carried on as follows:—

Ore containing 10 % or more of copper is directly roasted in rectangular stalls. The poorer ores are crushed by means of crushers and rolls and then dressed up to 10–12 % by means of hand jiggers, by women, or dressed on Frue vanners, until the average rises above 12 %.

The dressed ore is roasted in reverberatory furnaces, and then moulded into cylinders 0.35 ft. diameter, 0.2 ft. high and weighing 1⅔ lbs. each. After mixing with these cylinders material roasted in stalls, raw slimy ore, slag produced from matte smelting and a quantity of limestone, the product is smelted in a Piltz furnace, so as to obtain matte containing about 45 % of copper. The Piltz furnace can smelt about 4,000 *kwamme* in one day while in the same period of time a Japanese hearth smelts about 800 *kwamme* of roasted matte.

Formerly when silver ore was worked, the process resorted to was that of Kiss, and the reagents required, namely sulphate of lime and sulphide of calcium, were prepared at the mine.

Improvements in Metallurgy :—No remarkable improvements in the metallurgical processes have lately been introduced. Only a water-jacket has been fixed to the fore-hearth of the Piltz furnace while the matte is occasionally tapped into an iron pot where it is sprinkled with water so as to be conveniently stripped off in discs 0.01 or 0.02 ft. thick.

The gases coming out from the Piltz furnace have been obliged to pass through the dust-chamber into a roasting furnace, where they are burned, giving out heat sufficient to roast nearly 2,000 *kwamme* of ore in 24 hours.

Supply of Fuel :—Fuel is supplied from the state forests in the vicinity, and it seems that there exists no cause for anxiety as to quantity for many years to come.

Percentage of Extraction :—Crude copper is extracted at the rate of 75 % from undressed ore and 90 % from the concentrated ore.

Production Statistics of 1891 :—

Ore mined	4,261,681.00	*kwamme*.
Dressed ore.................	1,439,017.15	,,
Roasted ore.................	1,257,568.00	,,
Matte	298,527.90	,,
Black copper	127,455.92	,,

Expense of Working :—

Crushing	0.46	*yen*	per	100	*kwamme*	of dressed ore.
Dressing	0.51	,,	,,	100	,,	,, ,, ,,
Roasting	0.44	,,	,,	100	,,	,, roasted ,,
Ore-smelting	2.52	,,	,,	100	,,	,, ,, ,,
Smelting	0.35	,,	,,	1	,,	,, crude copper.

Steam Power :—A winding engine is used in the main shaft. There are two 40 horse-power Root's boilers which are used for

working the winding engine. The pumps used in different levels are as follows:—

No. 2 level......	2 Blake pumps—	8	inches	diameter.
No. 3 „	2 Klein „	10	„	„
400 ft., shaft ...	2 Special „	5	„	„
	1 „ „	$3\frac{1}{2}$	„	„

Two 10 horse-power French boilers, one 14 horse-power boiler, and one 7 horse-power boiler supply steam to engines for running 2 crushers, 2 rolls, 2 trommels, 1 hand-elevator, 2 Frue vanners, 2 Root's blowing machines which are used in connection with the smelting furnace, and 1 mill used to pulverize charcoal.

Distances to Markets:—

To Akita, Akita-ken	75	miles.
To Port Nojiro „	39	„
To Hirosaki, Aomori-ken..................	41	„
To Aomori „	65	„

KOKUSEI COPPER MINE.

Situation:—The Kokusei Copper Mine is situated at Kokubunji in Kawabe-mura, Shonan-gōri, Mimasaka Province, Okayama Prefecture; three miles from the town of Tsuyama and four miles from the District Office in Katsumata. The mine is well situated close to the river Yoshii, and is very convenient for traffic. Twenty miles down the river there is the town of Waki, where the Sanyō railway passes. Daily commodities are bought at Tsuyama and Katsuyama, and special stores at Kōbe and Osaka.

General History:—This mine is quite new, having been accidentally discovered fifteen years ago while digging a well some 10 feet in depth in a farm-yard. At that time a red oxide gossan was found and reddish-brown chalybeate water gushed out through the fissures. At first they were very much disappointed with their work, but after breaking a piece of the stone which had been dug out they found it to be a copper mine. Mese Genjirō began the exploration work, and in 1882, he got a lease and began mining. In February 1886 he transferred it to the present owner, Sugimoto Masanori who improved and enlarged the scale of working, by opening shafts, enlarging levels, laying down railways, and improving the smelting work. It is now the largest mine in this district.

Geological Formation and Ore Deposits:—The country rocks at this mine are clay-slate and tuff belonging to the Palaezoic Era. In the bed of clay-slate, ores occur in the form of irregular deposits surrounded by serpentine, some of them being so large as to weigh 2,000,000 *kwamme* while others are not larger than a pea; two or three deposits are sometimes found continuous and many

porphyrite veins traverse the large deposits. Many faults cause alterations in the formation so it makes exploration work very difficult.

Quality of Ore:—The ore found near the surface seems to be rich, and going further down it becomes poorer. On carefully examining a small deposit it is observed that the crust consists of serpentine. Inside there are small crystals of iron pyrites, and towards the inside, it gradually becomes cupriferous iron pyrites and in the center it is very rich copper. The cupriferous iron pyrites contain 3–8 % of copper, 40 % of sulphur and a trace of silver, sometimes associated with zinc-blende.

Length of Levels:—Mining is carried on with a shaft 180 feet in depth. There are 6 levels each 36 feet apart, and laid with rails. The total length of the main levels is more than 4100 feet, besides 4000 feet of branch levels and 28 winzes. The drainage level is 1300 feet long. It is 78 feet lower than the mouth of the shaft.

Cost of Mining:—The average expense of mining in 1891 was 1.10 *yen* per 100 *kwamme* of ore, and of this 60 % was expenses for exploration and the other 40 % mining expenses.

Metallurgy:—Around the mine there are many farms. As these are well cultivated the farmers do not allow roasting ore at the mine especially during the agricultural season. The roasting furnace and the smelting works are situated at some distance from the pit. It is very difficult to roast a great amount of ore excepting during the autumn and winter. For the above-mentioned reasons smelting on a large scale can not be carried on in this mine.

Roasting and smelting are carried on by the old Japanese process. The roasting of one charge of 30,000 *kwamme* of ore, requires about 60 days and consumes 3000–6000 *kwamme* of fuel, and loses 17½ % of its weight. The smelting of one charge, 1000 *kwamme* of roasted ore, in a Japanese furnace built with clay and sand provided

with two bellows, consumes 7.3 % of coal and 24 % of charcoal. Smelting twice (*Subuki* and *Mabuki*) in 12 hours, each taking 6 hours, with 6 workmen, will produce refined copper which contains about 98.5 % of the pure metal.

Percentage of Extraction:—The percentage extracted is 80–85 % of copper.

Cost of Smelting:—The cost of smelting is 1.38 *yen* per 100 *kwamme* of raw ore. The cost of 100 *kin* of refined copper, all expenses being included, is 12.00 *yen* on an average.

Fuel:—Charcoal is brought from a forest about 20 miles north, while fire-wood and timber come from the neighbourhood of the mine. Seven or eight years ago these materials were very cheap, costing 12–13 *sen* per 10 *kwamme* of charcoal and 2 *sen* per 10 *kwamme* of fire-wood, but at present charcoal costs for the same quantities 27–28 *sen* and fire-wood 5–6 *sen*. Coal is brought from Kiushiu.

Transportation:—Underground traffic is carried on by means of railways and the shaft is provided with a hand-winch.

On the surface the ore is carried in tubs from the pit's mouth to the smelting works by oxen. The copper produced is sent to Kōbe and thence it is exported to Calcutta and Singapore.

OSE COPPER MINE.

Situation :—The Ose Mine is situated in the village of Ose, Kita-gōri, Iyo Province, Ehime Prefecture, 20 miles from Matsuyama. It is some 2400 feet above the sea-level. The smelting works are built close to the mine.

General History:—This mine is quite a new one, discovered in Yamato by Kawano Seibey of Yoshino in April 1887. He had been searching for six months through Kiushiu, Chiugoku, and Shikoku, trying to discover a good mine.

Geological Formation :—The rocks are sedimentary, being chiefly schalstein belonging to the Archæan Era, and seem to have suffered from metamorphic action. In the upper part or roof, it is like clay, while in its lower part or floor it is a harder rock, however generally it is soft. It strikes N.W.-S.E. and dips N.E. The ore occurs in irregular deposits having forms not unlike form two plates put together. Some of these are 180 feet wide, 300 feet long, and 40 feet thick, and others are 100 feet square by 20 feet thick.

Quality of Ore:—The ore is common copper pyrites containing a very small percentage of silver with some lime, iron, and silica. It is very soft and powdery.

The percentage of copper is about 6 % of the original ore.

Length of Levels :—As this is a new mine the length of the levels is not very great, being only 1200 to 1300 feet.

Cost of Mining:—This costs 40–50 *sen* per 100 *kwamme* of raw ore.

Metallurgy :—The ore is first calcined in a kiln built of stone, 4½ feet wide, 20 feet long, and 4 feet deep. The bottom of it is inclined 40° from the rear to the front, and there are two air-holes; 4000–4500 *kwamme* of ore is calcined in one charge with 500 to 600 *kwamme* of fire-wood. It requires 60 days to complete an operation. The powdery ores are made into round balls with clay before subjecting them to calcination.

The stony ore is treated with a Japanese smelting furnace built with pulverized charcoal 1.2 feet deep by 1.8 feet in diameter. For black copper smelting it requires 13 hours and 5 workmen to smelt 300–400 *kwamme* of calcined ore with 40 % of fuel; the fuel used being charcoal and coke, and the fluxes used for smelting, silica and lime which is locally called *Senmai*. The powdery ore is treated with the wet process. The lixiviating tubs are arranged in three lines, one above the other. The first and second line are filled with ores and dissolved. In the last the copper is precipitated with iron, giving steam to make it dissolve easily and the precipitated copper is smelted in a small Japanese furnace.

Improvements on Metallurgy :—In former days one charge for smelting was 100 *kwamme* but it has of late been increased to 300–400 *kwamme* and the wet process introduced for treating powdery ore.

Fuel :—Although charcoal and fire-wood are not abundant in this district, it is not difficult to get them, 30,000–5,000 *kwamme* of charcoal being manufactured for monthly use, and coke is brought from Kiushiu.

Production :—The monthly product of black copper averages 8,000 *kwamme*.

Percentage of Extraction :—The percentage of extraction is 90 % on an average of the 5.5 % of copper contained in the raw ore.

Cost of Smelting:—For 100 *kin* of black copper this costs 6.50–7.00 *yen* on an average.

Use of Steam Power:—One 2 horse-power boiler is used for generating steam for warming the solution.

Transportation:—Both in and out of the mine transportation is carried on by manual labor; and horses are used for conveying fuel and manufactured copper. Copper is sent to Osaka or Kōbe by steamer.

IWAYA COPPER MINE.

Situation :—The Iwaya Copper Mine is situated at Iwaya and Tanibadoko, in Fukada-mura, Kuma-gōri, Higo Province, Kumamoto Prefecture, 9 miles from Hitoyoshi where the District Office is situated, 47 miles from Yatsushiro, and 72 miles from Kumamoto. The site of the smelting works is close to the mine.

General History :—Although the date of the discovery of the mine is not certain, it is said that it was worked about 180 years ago by Sagara, a feudal lord of this district, and produced a large quantity of copper. It was left idle after the year 1740, and in 1881 reopened by one Uyemura Kengo by name. After some transfers it was leased by Fukushima Tōkichi of Osaka. The scale of working was enlarged and improved by him.

Geological Formation and Ore Deposits :—The country rocks at this mine are clay-slate, radiolarian slate, sandstone and hornstone belonging to the Palæozoic Era. These are bounded by andesite and tuff of new volcanic rock.

Their strikes are from north to south dipping to west. The copper ore deposit is found in clay-slate, and manganese in hornstone. The thickness of ore beds in clay-slate is 15 feet in the widest part while only 1–2 inches in the thinnest.

Quality of Ore :—The average percentage of copper from raw ore is 6%.

Length of Levels and Shafts :—The longest level is 700 feet and the shaft only 50 feet.

Ore Deposits:—The ore deposits occur in the form of veins, of which there are three principal ones; two of them are called Tsurubi and Kamebi. They are parallel to each other, their strike is from the east to the west, dipping to the south with an inclination of about 75°. They often meet together and in that case they are very wide and rich. The remaining vein called Yokobi has a strike from the east to the west, dipping to the south, at a moderate angle; not more than 38°, and sometimes 10°. They are very irregular in their width, varying from one inch to three feet. This Yokobi vein probably crosses the two other veins, Tsurubi and Kamebi, in the lower part of these veins; therefore the future place of mining will be at the point of intersection. Besides the above-named veins there are many other workable ones.

Quality of Ore:—All the ore is known to be very rich and has the most splendid crystals of stibnite in Japan, although they are formed in other localities such as Hida, Kii, Tosa, Higo, etc. they are not such fine and large crystals. Its appearance is commonly divergent columnar or fibrous, with colour and streaks of lead-gray, shining lustre, and brittle.

It is used as an alloy to make other metals harder, such as type-metal &c. Crude antimony is exported for general use.

Levels and Shafts:—All the veins are worked with levels and shafts, some of the levels are 300 to 2000 feet long, and the shafts 50 feet to 150 feet deep.

Mining Expenses:—The mining expense averages 5.877 *yen* per 100 *kin* of ore.

Site of the Smelting Works:—The smelting works stand on the sea-coast at Sanchoba, Hinokuchi, Kampai-mura, Nii-gōri, Iyo Province, Ehime Prefecture, three miles from the Ichinokawa mine and only ½ mile from Saijō. They are thus very conveniently situated as regards the purchasing of fuel and other commodities.

Metallurgy:—Before the Restoration proper metallurgical operations were unknown, nor was the use of antimony well understood. In 1876 the Paper Currency Bureau of the Financial Department sent an order for refined antimony through the Ehime Prefectural Government to Kawabata Kumasuke, and others who were then the lessees of the mine. Although he presented himself at the Bureau with samples of his antimony, it failed to sell on account of its inferior quality. He then visited the Mining Bureau of the Public Works Department, and entered a request to give him instructions in the preparation of pure antimony. His request was accepted, and Mr. Godfrey, a foreign employé of the Bureau, gave him the knowledge he applied for. After that Kawabata could produce antimony so pure as to satisfy the officers of the Paper Currency Bureau. Now that Kawabata and his company have come to work the mine again, the method they follow is Godfrey's, which is as follows:—

Godfrey's method is in three steps:—

I.—The preparation of the sulphide.
II.—The preparation of crude antimony.
III.—Refining.

I.—Two crucibles set upon each other have a small hole bored through their bases. These constitute the essential part of the hearth used. It may be considered as a modified Freiberg vertical hearth. The upper crucible is filled with powdered ore from the mine and covered. Heat is given from below, using coal as fuel. As the ore smelts, it falls in drops into the lower crucible, from which it is ladled out into moulds. The smelted material thus prepared is antimony sulphide. This operation takes about two hours.

II.—As the ore smelts, a portion of it volatilizes. This volatile portion, being condensed and crystallized by preventing it from rising, is crude antimony.

III.—The crude antimony is again heated (as in I) after mixing with it suitable proportions of antimony sulphide, charcoal, soda, and coal. The product is refined antimony.

Percentage of Extraction:—The average percentage of extraction is 85 %.

Fuel:—Wood and charcoal are easily obtainable in the neighborhood of the mine. Coal is brought from Kiushiu.

Cost of Metallurgical Works:—The average is as follows:—

0.385 *yen* per 100 *kin* of antimony sulphide.
2.500 *yen* per 100 *kin* of refined antimony.

Production Statistics:—The monthly production of the ore averages 200,00 pounds and that of the antimony sulphide, 150,000 to 160,000 pounds.

Transportation:—The ore is carried out of the pits in ore-carriages. It is then pulverized, concentrated, and sent to the smelting works on horses. A horse-load is about 360 pounds and is carried in two bags. The manufactured product is shipped to Osaka, Kōbe, and other ports in boxes. The principal markets are Kōbe and Osaka, both of which are within a distance of 200 miles from the mine.

NEU IRON SAND MINES.

Situation:—The mines are in Hino-gōri, Hōki Province, Tottori Prefecture, and extend 28 miles from east to west and about one-third of that distance from north to south.

General History:—The date and circumstances of the discovery and location of the mines are quite unknown; neither books nor tradition state them. From the fact that nothing can be heard from the oldest people in the neighborhood, it is inferred that the mines must have been discovered more than a thousand years ago, for hundreds of years would not be sufficient to kill that long-lived verbal history, tradition.

What vicissitudes they underwent is also unknown, but one fact is certain that the amount of work at present is only one-sixth of that done before the Restoration, owing to the importation of foreign iron.

Expense of Mining:—This depends upon whether the year is dry or wet. In a wet year, *i.e.* one in which it rains and snows much from the autumn till the next spring, a greater quantity of the iron sand is obtained than in a dry year. The expense of mining averages 5 to 7 *sen* per 10 *kwamme*.

The season of mining is from the autumnal equinox of one year to the spring equinox of the next year, *i.e.*, when agricultural people have most leisure and when they need no water for irrigating their rice-fields. It is therefore principally the farmers that are employed in mining.

Position of the Smelting Works:—The smelting works are erected where it is most convenient to get a sufficient supply of fuel. After working for 14 or 15 years in one place, when the

wood in the neighborhood becomes scarce, it has been the custom from ancient times to remove to some other convenient place, no farther than 2 miles from the old site, as the iron sand is found almost everywhere in this vicinity. A sort of rotation system has thus come to be carried out both in the positions of the smelting works and in felling the forests.

Metallurgy before and after the Restoration (1868):— The metallurgical processes of to-day are the same as those practised prior to the Restoration. They are as follows: The iron sand is thrown into a furnace, smelted, made into cast iron, and then converted into wrought iron.

The method of making cast iron is thus: A furnace is built of clay 8 to 10 feet long, 2.5 to 3 feet wide, 3.5 to 3.8 feet high, and having walls 0.5 and 1.5 feet thick in their upper and lower portions respectively. Into this furnace charcoal and sand are alternately thrown and heated, strengthening the heat of the fire by means of eighteen to twenty pipes inserted on both sides at the bottom, and connected with bellows. The sand smelts after a time, and the molten mass is made to flow out of the furnace, allowed to cool for a time, taken into special reservoirs, placed near the furnace, further cooled and afterwards broken into small pieces. After repeating this several times for four days and nights, the furnace is broken and the work is temporarily suspended. This is locally termed "*one age.*" The cast iron produced during "*one age*" is about 1,500 to 2,000 *kwamme*. The quantities of iron sand and charcoal for producing this amount of cast iron are respectively 5,000 to 8,000 *kwamme* and 5,000 to 6,000 *kwamme*.

The clay of which the furnace is made contains much silica and therefore facilitates the smelting of iron sand. The furnace becomes thinner as the sand is smelted in it, and at the end of four days and nights, it is no longer fit for use.

To convert cast iron into wrought iron the former is first heated in heaps and made into adhesive masses, much of the carbon being

removed. These masses are again heated in a forge and then treated with hammers. This is repeated four times and wrought iron is the result.

The properties of the wrought iron obtained vary with the character of the earth of which the floor of the forge is made. This earth should be as argillaceous as possible and moderately moist. On the other hand the floor upon which the first heating is done should be as dry as possible. If these conditions are fulfilled good wrought iron is obtained, but if otherwise, the manufactured product cannot be of good quality. In this process of manufacture, how moist the forge floor should be is a question of no mediocre importance, for excess of moisture in it is as detrimental as its want, to the production of good iron.

In converting cast iron into wrought iron, a reduction in weight of about 37.5 % is usual, thus, from 100 *kwamme* of the former, about 62.5 *kwamme* of the latter is obtained. Each forge yields about 50 *kwamme* of wrought iron per day receiving about 80 *kwamme* of cast iron.

Improvements in Metallurgy :—Improvements in the metallurgical processes were commenced in 1887 and have continued up to this day. Those already achieved are as follows :—

a. Manual labor has been replaced by water power in forcing the air into furnaces and forges.

b. The height of furnaces has been increased from 3.5–3.8 feet to 5–6 feet thereby increasing the quantity of the cast iron made and lessening that of the charcoal needed.

c. At the Fukuokayama smelting works, a 10 horse-power steam boiler has been planted, and this operating upon a 4-inch and a 5-inch hammer, has made it possible to produce a large amount of iron. Another boiler of 6 horse-power has been set up to run a blowing machine used in heating wrought iron.

Supply of Fuel :—The supply of fuel is more than sufficient for the twenty-five forges. It would not be inadequate to the need

of even forty forges, as evinced in the fact that there were once as many in full work.

Production Statistics:—The product varies every year in quantity. The following are those of the last twelve months :—

I. From the Twelve Pig-iron Furnaces.

Pig-iron	24,000 *da*	= 720,000 *kwamme*.
Slag	3,000 ,,	= 90,000 ,,

Note.—One furnace produces on an average 2,000 *da* of pig-iron and 250 of slag. One *da* is equal to 30 *kwamme*.

II. From the Thirteen Steel Furnaces.

Steel	4,160 *da*	= 124,800 *kwamme*.
Slag	6,240 ,,	= 187,200 ,,
Pig-iron	10,400 ,,	= 313,000 ,,

Note.—The yearly produce of a furnace is 800 *da* of pig-iron, 320 of steel, and 480 of slag on an average.

III. From the Twenty-five Forges.

Wrought iron .... 40,500 *kwamme*.

Note.—The average yearly produce of a forge is 1,200 bundles or 16,200 *kwamme*.

1 *bundle* = 13.5 *kwamme*. Wrought iron is made from both pig-iron and slag. To produce 6.25 *kwamme* of wrought iron, 10 *kwamme* of pig are required, while of slag double as much is needed for producing the same amount of wrought iron. The slag from the cast-iron furnace is inferior to that from the steel one.

Transportation :—Where roads have been repaired, wagons are used ; where not, horses. The greater part of the transportation of the mine is done with wagons.

Expenses of Working :—The following are those of the last twelve months :—

Per 10 *kwamme* of Pig-iron.........	From	0.50	to	0.60 *yen.*
,, ,, ,, ,, Wrought iron..	,,	1.80	,,	2.00 ,,
,, ,, ,, ,, Steel...........	,,	2.00	,,	2.20 ,,
,, ,, ,, ,, Slag...........	,,	0.25	,,	0.30 ,,

Power :—Steam power is used only at Fukuoka-yama. Water power is utilised at Araya, Wakasugi, Onishi, Doyō, Tsugō, and other places. The water wheels used are quite large.

Markets :—The products are first taken to Port Yonako and thence to Port Sakai, 10 miles from the former, both by land and by water. From the latter port they are sent to Osaka or the northern provinces in the Yusen-gwaisha or Shōsen-gwaisha steamers. The distances from the different dressing houses to Port Yonako are from 10 to 35 miles. Ttransportation by land is for the greater part effected by means of wagons.

Workmen :—Those engaged in the construction of furnaces and manufacture of cast iron are called *murage;* those occupied in converting the cast into wrought iron, *daiku;* and those employed in puddling wrought iron, *sage.* The quantity of pig-iron manufactured in a given space of time depends much upon whether the *murage* are skillful or not, and both external appearance, strength, and other properties vary in proportion to the expertness of the *daiku* and *sage.*

Persons engaged in the iron industry think it pays to spend any amount of money to have their workmen properly educated and well experienced, for of all metallurgical arts the manufacture of iron is the most difficult.

YOSHIDA IRON SAND MINES.

Situation :—The mines are in Yoshida-mura, Iishi-gōri, Idsumo Province, Shimane Prefecture.

Ore :—The ore is iron sand and consequently the mine is not at one place for any long period of time. It is often moved from one place to another. The work of mining as now pursued, is after the old Japanese method. A hill containing iron sand is gradually destroyed and the sand is suffered to flow into a canal, which runs through the mining place. The ferruginous sand being heavier than the silicious, sinks, and is caught in a sink-hole. Thus partly purified, it is allowed to run on and thrice washed in its course, before it is subjected to furnace work.

This district is highly rich in iron and promises the possibility of continuing the mining work for several hundred years to come, even on a more enlarged scale than at present.

General History:—The important points to be mentioned under this head are as follows:

Tradition says that the iron mining in the district was commenced some 989 years ago.

It was 629 years ago that an ancestor of the present lessee commenced the iron industry. Tradition puts it at an earlier date, but nothing authentic is handed down, the household records having been destroyed in a fire sixty-three years ago.

Before the Restoration the feudal lords protected the industry perhaps for two reasons; viz., the importance of the industry itself, and the desirability of keeping the poor miners from rebelling against them.

The industry has had some prosperous days in the past.

At present it is very much embarrassed, and that for the following reasons: —

a. The lowering of the value of iron.

b. The importation of foreign iron.

c. The impossibility of introducing efficient machinery, for riotous and unlawful acts may be feared from the majority of the poor ignorant miners, thinking that they may thereby lose their means of living.

d. The want of protection from the government.

Cost of Mining:—The present lessee is mining at fifty different places and the average annual yield is 9,16,660 lbs. If, in the future, the balance of the supply and demand turns in his favor, he may increase the number of places and gain a much greater quantity of ore, unless there exists an old custom of limiting the iron miners in this district to a certain number.

The expenses are 5,500 *yen* for the above-mentioned quantity of ore, *i.e.* 6 *sen* per 100 lbs.

The miners are usually paid in rice.

The Works:—The works are more stationary than the mines. They are seldom moved unless economy demands it. The present lessee has them at five different places.

Metallurgy:—The ore washed as described above is again washed to get rid of all the disseminated sand. It is then thrown into a hearth, 4.5 to 7 feet deep. Charcoal is heaped upon the ore. Blasts are forced in by means of bellows worked by the foot. At the end of three days and nights the iron sand is fused and suffered to flow out. What flows out is pig-iron and what remains in the hearth is slag containing more or less pig-iron.

The main building of each of the five works is 100 feet from front to rear and also from side to side. In its centre there is a hearth for working the ore. The pig-iron made in it is allowed to

flow out and while yet hot is pounded flat on the ground with logs 8.5 feet long. The best part of it is then heated in a hearth of clay 9 feet long, 3.9 feet wide, and 3.5 feet deep. The pig-iron, mixed with charcoal, is thrown in a little at a time as often as seventy times per twenty-four hours. The air is forced in by means of two bellows placed beside the hearth. After being heated for three days and nights the hearth is destroyed and the contents, after have been exposed to the open air for twenty-four hours, are sent to the slag breaking works, where they are broken and divided into steel and slag. The steel which is locally called *kwako* in contradiction to what is termed *suiko* to be presently described, is refined, assorted, and sent to market. The slag and the pig-iron not fit for the manufacture of steel are worked in forges and made into wrought iron.

Of ores we distinguish two sorts, *masa* and *makome,* the former of which is coarser, and is used for making steel and the latter for manufacturing cast iron.

The contents of the above hearth are sometimes thrown into a pond and raised after about twelve hours. The steel so prepared is the *suiko* above referred to. It differs from the *kwako* only in hardness.

The mode of preparing wrought iron is as follows: The pig-iron is heated for about two hours in a forge and partially fused. The *sagezuku* or partially fused pig-iron has a certain proportion of slag added and the mixture is again thrown into a forge. Now charcoal is inserted into the melting mass, clay-water is occasionally poured upon it, and blasts are continually sent in. These operations are all done by eight experienced workers superintended by their chief, a *daiku* in the vocabulary of iron mines in Japan. The final step of working is hammering, for which iron hammers of 1,600 *momme* weight are used.

Improvements in Metallurgy:—The following improvements have been lately introduced at Yayedaki, where we have the best current of water for cleansing the ores :

Bellows have been abandoned and blowing machines introduced. Water wheels have been fitted up and hearths much enlarged.

The introduction of blowing machines has brought about the following results:

1. The durability of hearths increased from 2–3 days to 4–5.
2. Possibility of using large hearths.
3. Less labor required.
4. Production increased and extraction made more perfect as shown below:

PRODUCTION OF A HEARTH WORKED FOR FOUR DAYS.

With Bellows.		With Blowing Machines.	
Pig-iron	960 *kwamme.*	Pig-iron	1,350 *kwamme.*
Slag	300 "	Slag	450 "
	1,260 *kwamme.*		1,800 *kwamme.*

Supply of Fuel:—The present lessee has about 76,068 acres of forest land and therefore he has no fear of want of fuel. The trees in this district take from twenty-five years to forty years for growing to the size suitable for producing charcoal for furnace and forge use.

The annual consumption of fuel is as follows:

a. Hearths consume:	Charcoal	1,177,000	*kwamme.*
	Wood	360,000	"
b. Forges consume:	Charcoal	365,040	"

Production Statistics:—

Iron sand	9,166,660	lbs.
Steel	512,250	"
Pig-iron	2,237,750	"
Wrought iron	1,300,000	"

This quantity of pig-iron includes 638,500 lbs. of slag. All the pig-iron produced is not worked for steel and wrought iron. A portion is directly sent to market.

Rate of Extraction:—

1. One hundred *kwamme* of iron sand yield:

Pig-iron	21 *kwamme*.
Slag	7 „
Steel	2 „
	30 *kwamme*.

2. One hundred *kwamme* of iron sand worked for steel yield:

Steel	11 *kwamme*.
Slag	10 „
Pig-iron	9 „
	30 *kwamme*.

3. One hundred of mixed pig and slag yield:

Wrought iron	65 *kwamme*.

Cost of Production:—

a. Hearth expenditures	21,175.00 *yen*.
b. Forge „	24,334.89 „
	45,509.89 *yen*.

a. Hearth Expenditures Detailed.

Iron sand (6 *sen* per 100 lbs.)	5,500.00 *yen*.
Charcoal (4.5 *sen* per 10 *kwamme*)	5,178.80 „
Wood (1.4 *sen* per 100 *kwamme*)	410.40 „
Wages and miscellaneous expenses	10,085.80 „
	21,175.00 *yen*.

b. Forge Expenditures Detailed.

Mixed pig and slag	13,200.00 *yen*.
Charcoal	3,102.84 „
Wages and miscellaneous expenses	8,032.05 „
	24,334.89 *yen*.

Besides these sums the following quantities of rice are required:

Hearths	2,064 *koku*.
Forges	1,136 „

As to wages there exists a singular custom of raising or lowering them not in accordance to the fluctuation of general prices, but according to that of prices of steel and iron.

Power :—Steam is not used now, nor will it be in the near future. The use of hydraulic power has been commenced at Yayedaki as mentioned above. It is our hope to have it utilized in other places also ere long. Its use in connection with slag breaking apparatus has been so successful as to have halved the cost of labor.

Transportation :—

1. From the mine to the highway, on men's shoulders and horse-back.
2. From the junction of the mine road with the highway to Matsue, on wagons and in boats.
3. From Matsue where the present lessee has a branch office on the farther side of the lake to the markets, in junks or steamers.

There is a strange custom in this and other mines in this district as to selling horses to the wagoners. Certain prices are agreed upon, when the animals are given to them. After that they work unpaid for a number of years, until what they have earned amounts to the prices of the beasts.

Markets :—

To Matsue	30 miles.
To Osaka, Tokyo, Niigata and other ports in the north	250–1,000 miles.

MIIKE COLLIERY.

Situation:—The Miike Coal Mining Concession lies in lat. 33° North and long. 135° East in the Island of Kiushiu. The total area is about 16,000 acres, the half of which lies in the province of Chikugo, Fukuoka Prefecture, and the other half in the province of Higo, Kumamoto Prefecture. The colliery office is situated in the town of Omuta which contains about 20,000 inhabitants and which has rapidly grown to its present importance within the last few years. The town is close to the bay of Ariake and about two miles from the boundary line of the provinces of Chikugo and Higo. In the center of the town there is a station of the Kiushiu railway line which passes through the town and was opened for traffic in 1890. The Kiushiu railway line runs from the port of Moji to the city of Kumamoto, thence to be extended to Misumi, one of the export harbours for the Miike coal. The town has a Telegraph and Post Office and its principal features are shipping docks, mechanics' shops, etc. belonging to the colliery, and a cotton mill recently built, in which the colliery also has a large interest.

The climate of the place is moderate, the maximum temperature during the year is 95° Fah. and the minimum 19°.

General History:—No authentic record exists that gives the particulars of the discovery of the mine, but tradition is not wanting. It says on the 15th of January 1469 a farmer of the Inari village, Denjizaemon and his wife went to the Inari hill to gather some fuel, and being very cold there, they made a small fire on the black rock to warm themselves. How astonished they were when they found that the black rock took fire and burned well! This is the origin of the discovery of this colliery.

There were formerly three principal mines: namely Inari-yama, Iku-yama and Hirano-yama, the first two of which were worked by Viscount Tachibana, and the last by Mr. Ono Takamoto, up to the time when the Government bought them for the sum of 41,090 *yen* in 1873.

For the want of cammon miners, it was arranged that convict labour should be employed in the mine, and prisoners from the neighboring local prisons were introduced as miners, and soon after the management was transferred to the hands of the Government. The number of criminals so increased that in 1882 a special prison under the name of Miike Prison was established, with the intention of working the Nanaura mine wholly with its prisoners. This prison is under the direct control of the Home Department and now contains some 1600 convicts.

In 1876 the Government appointed Messrs. Mitsui & Co. sole agents for selling the Miike coal, the object being to extend the consumption of it in foreign countries. They immediately opened their offices in Hongkong, Shanghai and other ports of China and Japan and this greatly accelerated the important position which the Miike coal assumed in trade, both in China and Japan.

Since the Government assumed the management, many improvements have been gradually introduced, but up to 1878 the mining was carried on in a primitive fashion. The coal mined was carried in baskets on men's shoulder to the surface, and pumping was done by treading wheels. In 1878 new arrangements for the Oura mine, such as a new engine incline with a hauling engine on the surface, the Mitsuyama shaft and its ventilating furnace, a new tidal basin, and a lock gate at the mouth of the Omuta river, and a horse tramway from the mine to the new docks etc. were all completed and put into operation. Their completion marks a distinct epoch in the development of the Miike mine.

In July 1879 the sinking of Nanaura shaft was begun, and after much difficulty with it, was completed in June 1882, and mining operations commenced soon after. Immediately succeeding the completion

of the above work, the sinking of another shaft for ventilation was commenced and was completed in June 1883 and was directly fitted up with a fan engine.

In September 1883, some miscreant set fire to a coal pillar forming a side of the engine incline in the Oura mine. The smoke and gases from the fire immediately spread throughout the mine, and forty workmen and sixty horses lost their lives by suffocation. After it was found impossible to rescue any more, all the air ways were closed and sealed up to stop the further spread of the fire. In the meantime, water gradually rose in the mine and it was reopened for work. For the draining of the level portion of the mine thus drowned the Hayagane shaft was sunk and the work of drainage therefrom commenced in the latter part of 1887.

In 1886 the ground was opened up for beginning the Katsudachi shaft sinking. The work of sinking was laboriously carried on with a succession of disasters and difficulties until June 1889 when immediately after a heavy earthquake, an influx of water took place so suddenly that the pumps were drowned, and the water pumped up was 3,000 gallons per minute. The Mitsui Co. are determined to recommence the sinking, and two large compound differential pumping engines built by Messers Hathorn Davey & Co. of Leeds, are now in progress of erection at the pit's mouth, with the capacity for raising 6,000 gallons of water per minute. In February 1887 the Miyanoura shaft sinking was commenced and in August of the same year the coal was reached and machinery for winding etc. was placed in position and as that pit is near the existing horse tramway the work of mining was immediately commenced.

Since then great efforts have been made by the government to improve the colliery and enormous sums of money judiciously expended on the above-mentioned works. The investments proved to be a complete success and in few years this colliery became the largest in Japan. But the great strides which our nation has made within the last few years led the Government to transfer the colliery to a private party, and advertised that all the mines were to be sold by public

auction, for a sum of not less than 4,000,000 *yen*, and the working and management of the mines to be transfered to the highest bidder on 1st, January 1889.

The mines were transfered to the highest bidder, Sasaki Hachirō with Mitsui & Co. as guarantee on 1st January 1889 as stipulated, for the sum of 4,550.000 *yen* and Mitsui & Co. took the actual responsibility and management which was formally recognized by the Government in the following year.

Since the mines were placed under Mitsui & Co.'s management, the capacity of the mine has been greatly increased and several important improvements introduced, the most conspicuous among these are the construction of a new tidal basin with lock-gate, a railway from the mines to the new dock for locomotive conveyance, a loading pier at the docks, screening and cleaning machinery at the Nanaura and Miyanoura mines, endless rope haulage at Oura mine etc., etc.

Coal Seams and Quality of Coals:—Several seams of coal occur in the Miike coal field, but the first and second seams only are capable of being economically worked. The first seam, *uwaishi*, averages fully 8 feet in thickness of pure solid coal, without any interstratified bands of shale. This seam is remarkably uniform in quality and thickness over a large area as proved by expoliations and borings. Strike north-west to south-east with gentle angle 5 degrees toward south-west. The thickest parts often increase to over twenty feet in thickness of pure coal. The quality of the coal is of the best bituminous and most economical caking and steam-raising coal and fit for the manufacture of both coke and gas. The second seam, *banshita*, is only six to ten feet below the first seam and its thickness averages about six feet near the out-crops, but is more irregular and uncertain in the deeper portion. The strike and dip are similar to those of the first seam. This coal is free-burning and non-caking but its quality is inferior to that of the 8-foot coal. The second seam is now worked only on a limited scale for local consumption. Up to the present, the

mines in this seam, have been free from explosive gases and naked lights alone are used with impunity.

Both the hanging and the foot walls are of sand-stones containing some shell-fossils. The colour of the coal is not quite black, but dark brown, having rather a dull rusty appearance. On first being put on a fire it gives off great volumes of black smoke and softens almost like pitch, but soon hardens, cakes, and burns brightly, giving great heat with long flames.

The strata are composed of different kinds of sand-stones more or less coarse, porous, and fissured, which allow of an easy passage of water from the surface to the coal seam, thus, rendering the process of mining expensive and dangerous from flooding. But on the other hand the dip is comparatively gentle, and the roof is firm and strong and no considerable faults are found.

OUTPUT OF THE MIIKE COAL MINES FROM 1877 TO 1891 INCLUSIVE.

Year.	Amount of Coal in tons.	Year.	Amount of Coal in tons.
1877	54,589	1885	248,137
1878	78,207	1886	277,718
1879	120,186	1887	317,717
1880	118,211	1888	368,109
1881	168,899	1889	462,271
1882	156,430	1890	487,641
1883	158,592	1891	574,330
1884	209,775	—	—

EXPORT OF MIIKE COALS FROM KUCHINOTSU DURING 1877 TO 1891.

Year.	Tientsin.	Chefoo.	Shanghai.	Foochow.	Swatow.	Amoy.	Hongkong.	Saigon.	Singapore.	Manilla.	Batavia.	Rangoon.	Madras.	Colombo.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1877	209	—	200	—	—	—	—	—	—	—	—	—	—	—	409
1878	—	—	7,512	—	—	—	—	—	—	—	—	—	—	—	7,512
1879	—	—	24,067	—	—	—	—	—	—	—	—	—	—	—	34,067
1880	6,880	652	62,105	—	—	—	577	—	—	—	—	—	—	—	70,214
1181	7,958	2,729	55.467	—	2,348	—	—	—	—	—	—	—	—	—	69,002
1882	—	1,334	89,038	—	930	—	—	—	—	—	—	—	—	—	91,302
1883	1,176	1,252	56,882	—	2,802	—	15,177	—	—	—	—	—	—	—	77,289
1884	2,687	3,217	77,054	—	6,758	—	29,291	—	6,407	—	—	—	—	—	125,414
1885	—	1,650	81,864	—	10,953	—	85,405	—	—	—	—	—	—	—	179,872
1886	—	650	59,805	50	5.498	—	110,627	—	9,600	—	—	—	—	—	186,230
1887	—	651	54.739	—	9,119	—	116,917	—	11,724	—	—	—	—	—	193,150
1888	—	3,785	62,946	1,124	7,891	2,384	102,225	—	31,620	—	4.355	—	—	972	217,302
1889	—	7,064	106,027	604	13,237	—	141,196	—	9,331	—	—	1,450	—	—	278,909
1890	—	3,638	95,779	820	18,327	—	141,275	1,809	25,867	300	2,000	1,950	1,940	—	293,705
1891	—	735	76,878	1,900	13.521	1,600	190,335	—	20,875	2,850	—	3,000	—	—	311,697

Shafts :—The mines are worked with shafts, levels and inclines supplied with hauling engines; viz., No. 1, No. 2, No. 3, Nanaura, Miyanoura, Mitsuyama, Hayagane, and Katsudachi shafts of which the last is now in process of sinking. The sizes and depths of shafts and their uses are as follows:

No. 1. Nanaura shaft (round).	14 ft. dia.	230	for hoisting coal.
„ 2. „ „ „ ...	14 „ „	210	„ ventilation.
„ 3. „			„ the passage of miners.
Miyanoura shaft (rectangular).	12 × 18 ft.	168	„ hoisting coal.
Mitsuyama „ „	10 × 13 „	150	„ ventilation.
Hayagane „ „	9 × 13 „	267	„ drainage.
Katzudachi „ „	12 × 18 „	315	„ hoisting coal.

Production :—Average daily outputs of the principal mines are as follows:

Nanaura	800 tons per day.
Miyanoura	450 „ „
Oura..................................	400 „ „
	1,650 tons per day.

NANAURA MINE.

Mining :—The average daily out-put is 800 tons. The coal is mined by the pillar and stall system. The room is generally 15 feet wide and the pillar one chain or 66 feet square. At present, as far as practicable, the gangways or levels are driven in the direction of the strike from each side of the engine incline at certain convenient distances, say 500 to 700 feet apart. The engine incline is parallel to the dip and is now 3,000 feet long. The coal is mined towards the "rise" from the gangway so as to assist the handling of coal and the flow of water by gravity. Recently the room has been driven diagonally to the gangway to get the most advantageous haulage grade, so as to carry the tram up as near as possible to the working

faces. The pillar in this case is left in the shape of a rhomboid. The underground workings cover an area of 437 acres, two thirds of which is left as pillars.

Underground haulage:—The coal which is mined is either carried in shallow bamboo baskets on men's shoulders to the nearest loading place on the tramway where it is loaded into tubs, or where practicable the coal is charged directly into tubs at the working face. The tubs are wooden and with chilled iron wheels 9" dia. and can contain about 0.42 of a ton. These tubs in sets of 5 to 10 are drawn by horses to the engine incline and hauled up to the foot of the shaft by the engine. The main tramways underground are all double tracked with a guage of 20 inches. The rails are of the steel bridge type weighing 18 lbs. to a yard, but recently ordinary flat-bottomed steel rails weighing 14 lbs. per yard have been substituted and have been found superior in every way. The average grade of the engine incline is 1 in 12. The hauling engine is placed at the top of the incline about 30 yards from the shaft bottom. The engine has double cylinders each 16" dia. by 2 feet stroke geared 4 to 1 to two drums 6 feet dia., either one of which can be thrown into gear by a clutch while the other is loose on its shaft. There are now three landings from which the coal is drawn up the incline; the first landing is 1,730 feet from the engine, the second is 2,145 feet, the third is 2,722 feet. The hauling rope is Koebling's ⅞" cast steel wire rope and the number of tubs hauled up at one time is generally from 20 to 26. The farthest working face from the engine incline is 75 chains. The number of horses employed for drawing coal underground is 46 per day.

Winding:—The section of the winding shaft is circular and 14 feet dia., and 230 feet deep. The two cages balance each other. Each cage holds two coal tubs at a time. The head-gear is built of wood and is 53 feet high to the center of the pulley. Formerly the winding engine was a single cylinder engine 20" dia. by 3 feet stroke geared 3 to 1 to an 8 feet drum but the increasing demand for coal

necessitated its renewal, and in the winter of 1890 a new double-cylinder direct-acting engine with a conical grooved cast-iron drum built by Dickson & Co. of Scranton Pa., U. S. A. was erected on the opposite side of the shaft. The cylinders are 20" dia. by 48" stroke with Pooley's balanced slide valve; the largest diameter of the drum is 8 feet and the smallest 6 feet with brake in the middle. The engine is now working with entire satisfaction. The rope is Koebling's 1⅛" dia. cast steel wire rope of 7 strands of 19 wires each and when well greased, lasts over two years. The old engine is left in position and the drum, and driving wheel, governor, etc. taken off, the power being transmitted for driving screening machinery by wire rope. The surplus power is expected to be utilized for driving the proposed underground endless rope haulage.

Ventilation :—The ventilation shaft is the same as that of the winding shaft, but its depth is 210 feet. The fan is of the Guibal type 30 feet in diameter and 10 feet wide with 8 blades. It is now making on an average 23 revolutions per minute and discharging about 100,000 cubic feet of air per minute. There are two fan engines, horizontal high pressure and new condensing, with variable expansion slide valves. The engines are on the same bed-plate facing each other so that while one is working the other is resting. The fan is encased in a brick house with an escape chimney provided with a sliding shutter. The air is exhausted through an opening 10 feet in diam. one side of which is connected to an air-tight brick house built directly over the pit. The section of the underground air passages being large and having three air inlets, viz.:—the Miyanoura and Nanaura winding pits, and an inclined road from the surface to the Nanaura mine specially used as a passage for workmen in and out, the frictional resistance is small and it requires but little power to drive the fan. The mines being free from fire-damp, no serious difficulty has been hitherto encountered with regard to ventilation. The ventilation shaft has recently been provided with winding arrangements for lowering and raising men and materials by steam power.

Drainage:—Drainge is by far the most important item in this mine. The whole of the water made in this as well as in the Miyanoura and Oura mines, is pumped up to the surface from the winding and ventilating pits before mentioned. Nearly all the boilers are working for this purpose. Steam is taken down the ventilating pit and conveyed to different pump stations, the furthest one being 3,000 feet from the pit bottom. The position of the pumps, their kind, number, and size are given in the following table:—

PUMPS (NANAURA UNDERGROUND.)

Position.	Number.	Kind.	Size.
23rd Level	4	Tangy's Special	Steam cyl. 30″ dia. Water „ 11″ „ Stroke 48″
22nd „	3	„ „	Steam cyl. 24″ dia. Water „ 9″ „ Stroke 48″
3rd „	2	„ „	Steam cyl. 30″ dia. Water „ 11″ „ Stroke 48″
Winding-pit bottom.	2	„ „	Steam cyl. 21″ dia. Water „ 10″ „ Stroke 36″
„	4	„ „	Steam cyl. 24″ dia. Water „ 9″ „ Stroke 48″
Air-pit bottom	2	„ „	Steam cyl. 24″ dia. Water „ 9″ „ Stroke 48″
„	2	„ „	Steam cyl. 21″ dia. Water „ 19″ „ Stroke 36″
„	1	Davey's Compound Differential pump.	H.p. cyl. 12″ dia. L.P. „ 24″ „ Diameter of water cyl. 9½. Stroke 48″

The total quantity of water now pumped is about 3,500 gallons per minute. In the rainy season the pumps placed below the Hayagane pit are sometimes worked to assist in draining the Oura mine.

Screening and Cleaning:—All the coal is first dumped on to an oscillating bar-screen built according to Mr. Eckly B. Coxe's modification. It goes over the bars and drops on to a slowly

moving band, where on each side there are boys and girls, who pick out the stones and banded coals while the cleaned coals move on and drop into a wagon below.

The coals that go through the bar fall on to a gyrating-screen having a plate perforated with round holes. This screen is also built according to Mr. Coxe's patent with his permission, the details of construction being somewhat modified to suit the case. Here the coal is separated into "*nuts*" and "*smalls*," the latter of which drops directly into a wagon below, while the former falls on to a slowly revolving circular plate where the stones etc. are picked out by boys and girls and it is then dropped into a wagon. The driving shaft of the oscillating bar screen makes about 70 revolutions and the gyrating-screen 140 revolutions per minute.

There are two sets of screening arrangements, one set of which is capable of doing all the work while the other is resting.

Boilers and Chimneys:—The kind, number, and size of boilers are given below.

BOILERS (NANAURA SURFACE.)

Number.	Kind.	Dimension.	Pressure Carried.
6	Lancashire.	7 ft. diam. × 30 ft. long.	60 lbs.
6	"	6½ " " × 28 " "	60 "
3	"	6 " " × 30 " "	60 "
3	"	6½ " " × 28 " "	40 "
1	Eccentric Single flue.	6½ " " × 28 " "	40 "
2	" " "	6½ " " × 26 " "	40 "

About one hundred tons of coal are consumed in one day by these boilers. There are 2 square chimneys each 75 feet high, the internal opening of which at the top is 4.5 feet square, one round chimney 133 feet high and internal diam. 6 feet at the top, and 1 square chimney 83 feet high with an internal opening 4 feet square at the top.

MIYANOURA MINE.

Mining Method:—The average daily output is 450 tons. It is precisely similar in principle to that of the Nanaura mine, therefore no description is necessary.

The underground working covers an area of 110 acres, two thirds of which has been left as pillars.

Underground Haulage:—The general principle is the same as that of Nanaura. The engine incline is 2,300 feet long, and the hauling engine is an old double-cylinder engine having a cylinder 11" diam. by 2 feet stroke and gearing 3 to 1 originally having two drums 5½ feet in diameter rigidly connected together by a spur wheel but now one of the drums is taken off and the engine worked with one drum with a single rope. The number of tubs hauled at one time is less than 15. The average grade of the incline is about the same as that of the Nanaura incline. There are three landings, the first is 1,480 from the engine, the second 1,896 feet and the third 2,142 feet. The furthest working face from the engine incline is 46 chains. The number of horses employed for drawing coal underground is 10 per day.

Winding:—The winding shaft is rectangular in section 12 feet by 18 feet and is 168 feet deep. The cages, tubs etc. are precisely similar to those used at Nanaura. The winding engine is a double-cylinder engine with 14" diam. by 30 in. stroke geared 4 to 1 to a drum 8 feet in diam. The head gear is of wood 50 feet high to the centre of the pully, having a staging at the height of about 12 feet from the base, to which coal tubs are wound up and sent off to the screening house.

Ventilation:—The winding shaft serves as down cast and the foul air is discharged as at Nanaura from the ventilation shaft to which the workings are connected by air passages.

Drainage:—The principal body of water finds its way to pumping stations in Nanaura mine and thence is discharged to the surface. At present only 2—21" × 10" × 36" "Specials" and 3—14" × 7" × 24" "Specials" are used at the lowest working to pump water up to a trough from which it can naturally flow down to the Nanaura pump station. Steam is taken from the boilers on the surface.

Boilers and Chimney:—There are now only 3 boilers of Lancashire type, measuring 6 feet, diam. by 30 feet long and now 3 other Lancashire boilers measuring 65 feet in diam. by 28 feet long are in progress of setting.

The chimney is round and 104 feet high and 5 feet in internal diameter at the top. The boiler is now generally worked at 60 lbs. pressure.

Screening and Cleaning:—This is done in precisely the same way as in Nanaura with the difference that there is only one set of screening machinery instead of two as in the Nanaura. It is driven by a small engine placed on the side of the screening house.

OURA MINE.

Mining Method:—The average daily output is 400 tons. It is practically the same as in the other mines. At present the principal output is obtained from pillar robbing. The marked difference of working this mine from that of others consists in its system of haulage. The coal tubs are hauled up directly to the surface on a long incline by an endless rope. The incline is 4,824 feet long to the bottom. It has one sharp curve of 170 feet radius describing an arc of 75 degrees. The pitch of the grade which is constantly falling towards the bottom varies between 1 in 7 to almost a dead level which was the cause of much trouble for direct engine haulage until the introduction of the endless rope system. The engine for driving the

rope is an old one with double cylinders each 12" in diam. by 2 feet stroke originally geared 5 to 1 to two drums which were taken off and a conical pulley for driving an endless rope attached to one of the drum shafts. The endless rope is of the over rope system. The gripping is done effectually by simply kinking the rope. The empty tubs go down the grade by gravity, being held back by the grip and on an easy grade they move by the weight of the rope. The tension wheel is on the surface near the engine. The rope is $\frac{7}{8}$" Lang's steel wire rope. The usual speed of the rope is about $2\frac{1}{2}$ to 3 miles per hour. There are three landings on the incline tramway connected with horse tramways in the gangways by sidings from which the tubs are attached to the wire rope, the rope being kept high over the tramway to clear the tubs at the landing by vertical sieves. The first landing is 3,318 feet from the surface, the second is 4,242 feet, and the third 4,800 feet. The underground workings cover an area of 274 acres two thirds of which is left as pillars. The furthest working face from the engine incline is 73 chains. The number of horses employed for drawing the coal underground is 28 per day.

Ventilation :—The whole of this mine is ventilated by a furnace at the bottom of the Mitsuyama shaft, which has a rectangular section, 13 feet by 10 feet and 150 feet deep. The fresh air enters the mine from the incline as well as from other small former openings.

Screening :—There is one shaking-screen worked by men.

Boilers and Chimney :—There are three Cornish boilers each 5 feet in diam. by 24 feet long working at 35 lbs. pressure and a square chimney 75 feet high having an internal opening of 3 feet square at the top.

Drainage :—All the water drains off naturally through pipes built in dams separating the Nanaura and Oura workings and is pumped up to the surface either from the Nanaura pits or from the Hayagane shaft.

Surface Conveyance :—The Nanaura and Miyanoura mines are connected with the new railroad. The screened and cleaned coal after being filled into waggons, is weighed and then drawn by locomotives to the loading-pier at the new basin from which it is dumped into shales and loaded into barges carrying on an average about 100 tons. The Oura mine is connected with the old basin by a horse tramway. The same coal tubs used underground are drawn by horses in sets of three to seven or eight at a time and dumped into barges.

Railroad and Rolling Stock :—The new railroad is built with 3 feet 6 inches guage to conform with the Japanese Government Standard. The road is a single track and begins from the Nanaura mine, and passing near the Miyanoura mine, gradually rising and passing over the Kiushiu Railway line, continues on a high level to the pier. The rails are of steel weighing 35 lbs. per yard. The distance from Nanaura to the pier is two miles. The road, however is now extended to the Katchidachi shaft which is about one and half miles inland from Nanaura.

The smallest curve is of ten chains radius and the steepest grade against load is one in one hundred. There are two piers at the basin, one is the loading-pier running parallel to and close to the side of the basin and is 680 feet long, the other is used for storing coal and is parallel to the other but some distance off, and the length of it is 450 feet. Both piers are of wood.

Locomotives :—The company owns three Tank locomotives with 4 wheels, one English and the others American. The English has 12″ x 18″ cylinders and weighs about 22 tons in working order; the American engines are built by Baldwin and have 9″ x 16″ cylinders and weigh about 11 tons in working order.

Wagons :—The wagons are modifications of 5 ton wagons used in the anthracite region of Pennsylvania, but hold only 4 tons as

the guage is narrow. The company owns 100 of these wagons besides trucks for carrying materials.

Wet Basins and Lock Gates :—There are now two basins for loading coal, connected together by a narrow water passage. Each has its lock-gate which is 36 feet wide and has about ten feet of water at ordinary high tide. The older basin is a narrow sheet of water covering about 3 acres, and there is another lock-gate which is older. The basin inside this gate covers the area of 2 acres but is now seldom used for coal-loading.

The new basin covers an area of 4½ acres, and most of the shipping is done in this basin. It has always more than ten feet of water. In order to accommodate the passage of barges the sea bottom outside the lock-gates for a breadth of 130 feet has been dredged for a distance of more than a mile. One Priestmuth's dredger on an iron boat is being worked constantly to clear the passage as well as the basins from accumulating mud.

Steam Tugs and Coal Barges :—The company own 4 tugs for towing the coal barges to Kuchinotsu or Misumi harbours. For carrying the coal to the above-named parts, there are some 200 coal barges among about 30 of which are directly owned by the company and the rest by private individuals. The barges generally make trips by sailing.

Machine Shops :—The machine shop for repairing and making ordinary mining machinery, is near the edge of the oldest basin. The blacksmith's shop covers 550 square feet, the foundry 474 square feet, the finishing shop 516 square feet, and the wood working shop 190 square feet besides which are the store-house, drawing-office, etc.

All the machinery in the finishing shop, blower for cupola, and smith fires etc. are moved by an engine.

At the mouths of the three mines there are branch-shops of which the Nanaura shop is the largest and its machinery is moved by an engine.

Deep Boring:—Since 1877 up to the present more than twenty bore-holes for prospecting and other purposes have been made with the old-fashioned jumper drills and iron rods, the deepest hole hitherto bored by this method is 600 feet deep.

The constantly increasing depth of future prospectings, as well as the convenience of making larger holes for other purposes, required some better system and it was at last decided to try the American system of rope boring.

The complete rig was put up in September last and boring was commenced with an 8" bit which was changed to a 5" bit at the depth of 500 feet and proceeded down to 800 feet, where coal was reached with entire success, save some little trouble on account of the inexperience of the workmen and the novelty of the system.

The time occupied in boring, with the exception of time spent in repairing etc. was 250 days and, therefore, the daily progress was over 3 feet per day—which is about 3 times the average progress with the old jumper. The average cost per foot is about $1.50 including the cost of coal. These facts certainly speak favourably for rope boring when everything is considered.

AVERAGE DAILY NUMBER OF WORKMEN EMPLOYED ABOUT THE MINES.

	Nanaura.	Miyanoura.	Oura.	Total.
Miners and carriers	520	380	300	1200
Timbermen, Pitmen, Labourers and Helpers	370	210	250	830
Pumpers and Enginemen	43	10	6	59
Firemen	70	10	8	83
Pointmen, Wagon pushers, and Labourers in Conveying Department				230
Blacksmith, Fitters, Founders etc. and Coolies in Machine Shop				250
Carpenters, Coolies etc., in Building Department				110
				2,562

TAKASHIMA COLLIERY.

Situation:—The Takashima colliery is situated, in lat. about 32 degrees north and long. about 129 degrees east in the island of Takashima seven miles south-west of Nagasaki. It is 162.13 acres in extent and 2.31 miles in circumference. Its highest point is 375 feet above the sea.

General History:—When coal was first discovered here is unknown, as there exists no record bearing upon it. It is, however, known that a blacksmith of Fukahori village oposite to the colliery used coal in his forge more than a hundred years ago. This puts it beyond any doubt that its discovery must have taken place more than a century ago.

About ninety years ago, one Goheida from Hirado worked the colliery and sent the coal he extracted to the salt-works in different parts of the country. Fourteen years later it came into the possession of Fukahori, a vassal of the feudal lord of Saga, who also sent the produce to the salt-works of Shikoku and Chiugoku. In 1868 Matsubayashi Genzō, a vassal of Nabeshima Kanso of the Saga clan, and Mr. T. B. Glover, an Englishman, sank a shaft, 150 feet deep, for extracting the 8-foot seam at Honmura under the direction of the feudal lord into whose hands the claim then fell. Four years later another shaft, 138 feet deep, was sunk for the extraction of coal from the 18-foot seam at Obama. Of these two shafts the former was termed Hokkei shaft and the latter, Nanyō shaft.

In 1873, when the new Mining Law was first promulgated, the Government took the claim into its own hands after paying some 360,000 dollars for it.

In December 1874, the claim came to be managed by Mr. (Now Count) Gotō Shōjirō. He drove a level at Obama in 1876 for the purpose of extracting the 10-foot seam called Gomagoshaku. This level was named No. 2 Pit and the Nanyō shaft, No. 1 Pit. The Hokkei shaft had been abandoned before this time.

In March 1881, Mr. Iwasaki Yatarō became the new lessee of the mine. Under him and his successor, who still holds the claim, the mining work has undergone great and manifold changes for the better.

Before 1868 the produce had by no means been considerable, but it yearly increased for many years after it came under the management of the Saga clan and in 1888 and 1889 the greatest possible quantities were extracted. The daily yield was 1,200 tons.

After 1889 the pits showed a gradual decrease in their productiveness and in December 1890 the Goma-goshaku seam (No. 2. Pit) become totally unfit for profitable working and the No. 1 Pit, though producing about 300 tons per day at present, threatens to become useless within a year. The pit opened at Hyakumazaki and called No. 2 Pit at present, at first promised to be fit for extracting the upper 8-foot seam, but this proved impossible on actual excavation, because of the narrowness of the place and the abundance of faults. In digging this pit, however, an 18-foot seam was unexpectedly found out in the sea, and it is now yielding 170 to 180 tons per day.

Geological Formations:—The rocks of this mine are the sedimentary ones of the Tertiary Period. Coal, sandstone, shale, and other rocks are seen in strata. The claim has thirteen coal seams of which four are workable, viz.; the upper 8-foot, 10-foot Goma-goshaku, 5-foot Banto-goshaku, and 18-foot seam. Those under three feet are not worth mining, because the coal from them is generally of an inferior grade. The coal from the four seams above named is very good being inferior to none but the English Cardiff coal. Its specific gravity is 1.252 and its chemical composition is as follows:—

Water	1.800 %
Volatile matter	35.500 „
Ash	6.350 „
Coke	56.400 „
Sulphur	0.720 „

Cost of Mining :—The cost of mining one ton of coal is 1.364 *yen* as detailed below :—

Expenses.—	In pit mining and transportation etc.	0.771
„	Out of pit	0.047
„	Machines and implements	0.269
„	Office expenditure	0.238
„	Miscellaneous	0.039
		1.364

Production Statistics :—The production prior to the time of Messrs. Goto and Iwasaki cannot be ascertained owing to the frequent change of the lessees. The total quantity extracted for the period of 17½ years, when the claim was under these two gentlemen is about 3,900,000 tons.

Transportation :—In the shaft bottom No. 1 level is laid with rails and engine inclines following the dip of the coal-seam are built. Stations are located at the junctions of the gangway with the engine incline. All these levels and inclines have rails laid on them. Coal is taken on men's shoulders from the working faces to the gangway and thence to the stations in tubs. These tubs are drawn on an engine incline to the No. 1 level by the underground winding engine and thence drawn by horses to the shaft bottom, and afterwards hauled up by the winding engine built on the top of the shaft.

Railroads run out of the pits in many directions, and tubs full of coal are drawn to the jetty by means of self-acting inclines, while tubs which contain rubbish, are conveyed by horses or men.

Use of Steam as a Power:—At present eight Lancashire boilers are used for working the various engines in and out of the pits. When the mine was most productive, fourteen of them (490 horse-power in all) were used. The following are the numbers of the principal machines used at the time of the greatest prosperity of the mine:—

1–Winding Engine in shafts.
4–Underground Winding Engines.
2–Ventilators.
15–Eighteen-inch Special pumps.
2–Fifteen-inch Special pumps.

Principal Markets:—The principal markets are Nagasaki, Yokohama, Shanghai, and Hongkong. The following table gives the quantities of coal sent to these markets for the last three years:—

Markets.	1889.	1890.	1891.
Yokohama	98,670 Tons.	69,980 Tons.	56,750 Tons.
Shanghai.....................	58,023 „	49,587 „	48,821 „
Hongkong	82,914 „	106,303 „	79,827 „
Nagasaki.....................	135,205 „	175,916 „	79,827 „
	374,812 Tons.	401,786 Tons.	265,225 Tons.

NAKANOSHIMA COLLIERY.

Situation :—The Nakanoshima coal mine is in an islet situated close to Takashima Island, or nearly three miles to the north-west of Takahama Village, Nishi-Sonogi-gori, Hizen province, Nagasaki Prefecture, and some seven miles south-west of Nagasaki. It is about eight acres in extent.

General History :—The following are the chief points to be mentioned under this head :

In the year 1874, Maoki Miné of Fukahori Village, Nishi-Sōnogi-gori, thought he might find coal seams in this islet judging from its geological analogy to the Takashima.

October 1875.—He obtained permission from the Government to make a trial excavation.

February 1877.—Prospecting begun.

April 1877.—Over 170 feet bored and an 8-foot seam reached. A little while later clearing land about the boring commenced and in December 1878 over two thirds of an acre of open land obtained.

January 1879.—The sinking of a shaft commenced.

May 1st 1880.—The coal reached. All this time, freshets, storms, machines getting out of order, and other causes gave him no little trouble.

February 1883.—Coal won for the first time.

April 8th 1884.—Ordered by the Government to stop the work on account of his loan from the Government.

July 31st 1884.—The colliery returned to the Government.

September 15th 1884.—Leased to the Mitsu-bishi Co. At first the output was in small quantities. What the lessees did was mainly dead work.

June 1886.—The winding engine to the shaft completed.

July 1886.—No. 1 winding engine for the underground engine incline set up and the output of coal increased.

April 1889.—No. 2 winding engine for the underground engine incline made ready for use and the output still more increased.

At the end of the same year the quality of coal extracted showed deterioration.

August 1890.—Water inundated a great part of the mine.

The present production is about 500 tons per day.

Coal Seams:—The uppermost seam is 8 feet thick and the lower one is a 3 or 4 feet below the former 3-foot seam. Below them there are one or two seams and at the depth of 360 feet there is another 6-foot seam. What is now worked is only the uppermost. The coal from it is of an admirable quality and is suitable for use in boilers. Its chemical and physical examination shows:—

Water	1.60 %
Volatile matter	37.70 ,,
Ash	3.35 ,,
Fixed Carbon	57.30 ,,
Sulphur	0.31 ,,
Specific gravity	1.236

General Remarks:—This colliery has two shafts, No. 1 shaft, 200 feet deep, used for winding up coal, and No. 2 shaft, 186 feet deep, chiefly for the miners to go up and down by. The underground levels are 1380 feet long to the north-west of the engine incline and 2,400 feet long to the south-east of it. The coal extracted is taken on men's shoulders from the working face to the wagon roads or gangways and there it is put into tubs. These tubs are drawn by laborers to the bottom of the incline. On the engine incline 8–10 tubs are hauled up from the bottom of the shaft by the wires through 6-inch holes from the two winding engines provided on the surface for this purpose. Thence they are wound up to the top of the shaft by a

winding engine. Out of the pit coal is taken to the pier by a self-acting incline and thence sent to Nagasaki in coal boats.

There are 22 Lancashire steam boilers, each 30 nominal horse-power, for use in moving various engines both in and out of the pit.

HASHIMA COLLIERY.

Situation:—The Hashima Coal mine is on an isolated island about 5 miles west of Takahama village, Nishi sonoji-gōri, Hizen Province, Nagasaki Prefecture and over seven miles south-west of Nagasaki, and close to the Takashima Colliery.

General History:—The following are important historical facts:

The date of discovery is unknown.

1869—Embankments against tides were first constructed and mining work was started by opening drifts. After that the lessees of the mine, Maoki Miné and his company, had years of adverse fortune through visitations of storms and inundations, with only occasional periods of good fortune.

1883—The mine came under a new lessee, Nabeshima Magorokurō by name.

1886—The shaft and drift were further excavated and the daily output of coal rose to 70 or 80 tons.

1890—The Mitsubishi Co. became the new lessees and started work for improvements and enlargements not yet completed.

The present daily output is some 150 to 160 tons.

Coal seam, Geological Formation, quality of coal etc. etc.:—Geology and chemistry give a similar description of this mine as that of the Nakanoshima colliery, only the beds are not in the same position in consequence of faults.

The shaft, which is for winding up coal, is 130 feet deep and the level runs some 1560 feet westward from the base of the shaft.

The modes of transportation are the same as those practised in the Nakanoshima colliery.

For use with various engines in and out of the pit, there are 8 Lancashire boilers, 231 nominal horse-power in all.

ISHIKARI COAL FIELDS.

Hokkaidō Tankō-Tetsudō.

PORONAI, IKUSHUNBETSU, SORACHI AND YUBARI.

There is one large plain along the Ishikari river on the west part of Hokkaido. The Ishikari river is fit for the anchorage of one thousand ton steamers. It is very convenient, communicating with the Japan Sea on the north-west and the Pacific Ocean on the east. On the eastern part of this plain there are some coal fields which extend about 50 miles from north to south. They are divided into three large districts namely: North, Middle, and South.

North District:—This contains the Sorachi coal field, extending between the rivers Sorachigawa, and Kami and Shimo Utausugawa.

Middle District:—This contains the Poronai and Ikushunbetsu coal fields which are along the river Ikushunbetsugawa.

South District:—This contains the Yubari coal field. It lies along the Yubari river. The one which is along the Shihorukabetsu river, being very important, is included under Yubari coal field. At present, therefore, there are four collieries in Hokkaido, viz. Sorachi, Ikushunbetsu, Poronai and Yubari. The position of the collieries is as follows:

POSITIONS OF THE FOUR MINES BELONGING TO THE COMPANY.

Mine.	Province.	Country.	Village.	Local name.	Height above sea.	Distance from Muroran.	Distance from Temiya.	Distance from Sapporo.	Long. East	Lat. North
Poronai	Ishikari	Sorachi	Poronai	—	295 ft.	92 m. 2,891 ft.	56 m. 219 ft.	34 m. 999 ft.	141° 55′	43° 13′ 46″
Ikushunbetsu ...	„	„	Ikushun-betsu	—	265 ft.	95 m. 14 ft.	58 m. 2,622 ft.	36 m. 3,402 ft.	141° 58′ 4″	43° 16′ 1″
Sorachi	„	„	Nae	Benke-otashinai	418 ft.	114 m. 2,474 ft.	77 m. 5,082 ft.	56 m. 582 ft.	142° 3′ 5″	43° 31′ 5″
Yubari............	„	„	Tokawa	Shihone-katetsu	1,093 ft.	86 m. 1,225 ft.	97 m. 1,982 ft.	75 m. 3,762 ft.	141° 59′ 42″	43° 4′ 4″

The heights above the sea are those from the sea-level at Temiya to the centre of the railway-station at each mine, and the distances from Muroran, Temiya, and Sapporo are those from the centres of the railway-stations at those places to the centres of the railway-stations at the mines.

General History:—The Ishikari Mines were first discovered by Matsuura Takeshirō between 1855–1860 when he travelled up along the Sorachi river, but nobody cared about them, not understanding the use of coal at that time. After that, in the year 1864, Kimura Kichitarō of Ishikari, found out the outcrop of a coal seam when he went to the mountains to cut timber. He brought home a piece of it, without knowing what it was, but found it to be coal after showing it to Konno Matsugorō, a hunter of Shimamatsu. He went on a prospecting expedition to Poronai in the year 2871. Taking back a few samples of it, he presented it to the Colonial Office at Sapporo for examination. Just then the Office had two many other things to attend to, to institute an immediate inquiry into this important discovery. In 1872, one Hayakawa Chōjūrō of Sapporo heard of this and after making personal observations of the exposures, reported in detail what he had seen to the Colonial Office. Viscount Enomoto Takeaki who was then in Sapporo, as Secretary of the Colonial Office, had a personal interview with this man, and made a scientific examination of the substance which the latter had brought with him from Poronai and found it to be not less valuable than the coal worked at Takashima, Hizen.

In July 1873 the Colonial Office sent an American employé, Lyman, a geologist, to the spot. He found several coal seams of workable value. The next year but one he was again sent to ascertain the position, thickness, length, etc. of the strata, while the qualitative analysis of the coal was entrusted to an American mining engineer, Monroe, also an employé of the Colonial Office.

In 1874 Lyman published a geological map of the Hokkaidō coal fields and at this time it became known to the world that the Ishikari coal fields were valuable to work.

In 1879 Col. Crawford, an American mining engineer, planned the opening of the Poronai colliery and Gojot, an American civil engineer, designed the railway between Otaru and Poronai for transporting the coal. In 1880 dead work was commenced. In 1885, the Department of Agriculture and Commerce opened the Ikushunbetsu mine which

had been found by Shimada Junichi and Yamagiwa Eigo, geological surveyors of the Colonial Office, but it was stopped after a short working. In 1888 it was reopened by Murata Tatsumi. In the same year Ban Ichitarō, a geological surveyer found the Yubari coal field.

In December, 1890, the Hokkaidō Colliery and Railway Co. were formed. The railways, Poronai–Ikushunbetsu line and Poronai–Otaru line, were designed to be built and Sorachi and Yubari collieries to be opened, also Sorachi–Muroran and Sorachi–Yubari lines to be connected. All these works were completed in the year 1892. The yearly produce has steadily been increased in wonderful proportions, and the collieries now enjoy well-known prosperity.

Geological Formation:—The form of the land seems to be of strata of both old and new formation, so that the land of the new strata in the Tertiary Period along the Ishikari plain is very low and hilly; but the land of the old strata of the Tertiary Period or of coal-bearing strata is rather steep, and the land of the new strata of the Mesozoic, still more so. All the streams flow westward across the north and south strike of strata.

The thickness of coal bearing strata on the north or Sorachi coal field is some 4,000 feet and on the south or Yubari it is some 3,500 feet, the conglomerate lies under it and bounds the Mesozoic shale. The thickness of the conglomerate is more than 500 feet on the north, and in some parts it is interstratified with thick sandstone beds and the Mesozoic shale lies below it.

The coal-bearing stratum or old stratum of the Tertiary with, conglomerate or Mesozoic shale under it is regular; but the new stratum of the Tertiary is very irregular and surrounds the coal-bearing strata. There are thirteen coal seams in Sorachi over three feet thick. They are not of the same thickness, but some of them may be profitably worked. In Kami-utausunai three seams of No. 8, 9, and 10 are workable, others cannot be worked on account of faults. In

Shimo-utausunai some parts of No. 1 and 2 seams, and three seams of No. 3, 4, and 9 are workable. In Ikushunbetsu and Poronai four seams each, and in Yubari two seams only are profitably worked.

Although the number of coal seams is unequal, there is not much difference in their thickness. No. 9 Sorachi and the upper strata of Yubari, being the best and thickest seams are on the upper part and on the same level. The lower seam of Yubari and No. 3 seam of Sorachi may be on the same level. The upper strata of the Sorachi coal field and the strata of the Poronai and Ikushunbetsu coal fields, having the same condition, may be on the same level; No. 9 Sorachi, No. 1 of Ikushunbetsu and Poronai, and the upper seam of Yubari may be on the same level and are the best seams. There are many other seams but not on the same level and unequal in thickness.

In the following table some interesting particulars relating to these coal seams are given.

No. 9 Sorachi.	No. 1 Ikushunbetsu.	No. 1 Poronai.	Upper seam Yubari.
Roof Shale.	Roof Carboniferous Shale.	Roof sandy shale.	Roof Shale.
6 foot Coal.	4 foot Coal.	2.4 foot Coal.	3.7 foot Coal.
4 „ Shale.	0.4 „ C. shale.	0.03 „ Shale.	0.2 „ Bad coal.
7 „ Coal.	3 „ Coal.	1.4 „ Coal.	1.2 „ Coal.
Floor Shale.	2.8 „ Bad coal.	Floor sandy shale.	0.2 „ C. shale.
—	0.4 „ C. shale.	—	0.4 „ Coal.
—	3 „ Bad coal.	—	0.4 „ Sandstone.
—	Floor shale.	—	0.5 „ Coal.
—	—	—	0.1 „ Bad coal.
—	—	—	7.1 „ Coal.
—	—	—	1.0 „ Bad coal.
—	—	—	3.0 „ Sandy shale.
—	—	—	8.5 „ Coal.
—	—	—	Floor shale.

Although the strikes of the seams course north to south on an average, they vary in some places and also the dips are different in every case; in one place it is very flat, or sometimes vertical, and a great many faults occur in the Sorachi coal field, where it is the most steep; the Ikushunbetsu comes next. Poronai and Yubari have gentle dips and not so many faults as the former.

Quality of Coal:—The quality of coal is different according to the place, but not to the seam or in other words, the same seam in another place is of a different quality, and different seams of one place are of a similar quality; therefore it may be divided according to the place, such as Sorachi, Ikushunbetsu, Poronai, and Yubari; for instance, Sorachi coal is of a black colour and has less lustre, toward the north it is less caking, and more caking to the south; at Shimo-utausunai it becames quite caking. Both the Poronai and Ikushunbetsu coal are of a brown colour and have the finest lustre, but Poronai coal is non-caking and smoke-less, while Yubari coal is of a brilliant lustre, and gives off more smoke. So the qualities are different according to the places the analyses are shown in the following table.

Analyses of Coal.

	Poronai.				Ikushunbetsu.			Yubari.	Sorachi.		
	No. 1. Seam.	No. 2. Seam.	No. 3. Seam.	No. 4. Seam.	No. 1. Seam.	No. 2. Seam.	No. 3. Seam.	Upper Seam.	No. 8. Seam.	No. 9. Seam.	No. 10. Seam.
Specific gravity	1.235	1.298	1.244	1.223	1.205	1.229	1.223	1.20	1.231	1.212	1.214
Moisture	5.23 %	3.64 %	5.59 %	4.99 %	2.26 %	3.57 %	3.64 %	1.46 %	2.34 %	3.66 %	2.84 %
Dried at 110° C. Ash	6.19 „	17.24 „	6.62 „	3.20 „	5.94 „	5.18 „	4.18 „	4 57 „	5.35 „	2.38 „	4.56 „
Dried at 110° C. Coke	60 40 „	66.10 „	58.92 „	55.64 „	50.93 „	57.69 „	58.45 „	57.11 „	60.35 „	59.98 „	59.56 „
Dried at 110° C. Carbon in coke ...	54.21 „	48.66 „	52.31 „	52.44 „	44.98 „	52.52 „	54.25 „	52.54 „	29.99 „	57.60 „	54.99 „
Dried at 110° C. Volatile matter ...	39.60 „	33.90 „	41.08 „	44.36 „	49.07 „	46.31 „	41.56 „	42.89 „	39.65 „	40.02 „	40.44 „
Dried at 110° C. Sulphur...............	0.372 „	0.508 „	0.439 „	0.406 „	0.292 „	0.386 „	0.354 „	0.311 „	0.963 „	1 084 „	0.459 „
Color of ash	Reddish grey.	Whitish grey.	Light reddish grey.	Whitish grey.	Light reddish grey.	Light reddish grey.	Light reddish grey.	Light reddish grey.	Grey.	Reddish grey.	Purple grey.
Physical properties of coke	Slightly Coherent.	Fragile.	Slightly Coherent.	Slightly Coherent.	Coherent.	Coherent.	Coherent.	Sound.	Sound.	Sound	Sound.

The Ikushunbetsu mine has four seams, but in the table only three are given as the coal from the fourth has not yet been chemically examined. The Yubari mine has two and the Sorachi, nine seams, but so many are not mentioned in the table for the same reason as said above with regard to the Ikushunbetsu field.

Mining:—An adit level has been opened at the lowest level of the outcrop of the coal seam. Working is carried out along the strike of the seam and does not rosscut the strata except at the main adit level of Poronai. It is in the best position and connects from the west to the east sides of Poronai saddle seam. The present workings are above the water level, but the future object will be gradually to work lower than the water level. In Yubari an incline was opened and in Sorachi it is intended to do so. The working method is a long wall system at present but the breast system has also been tried. The ventilation was for a longtime left to nature by the means of winzes, But the ventilation not being sfficient for the extensive working in the mine. A Girber's fan was built. It is run by a 2 horse power boiler. Two 35 horse power boilers were set up at Yubari for the purpose of pumping water with a Cornish condensing pump patented by Bubcock and Willcock. Although a horse whim is used now, 8–60 horse power Lancashire boilers each 6½ feet diam. and 24 feet long, are being set up for working the winding engine, fan engine, and pumps. Four boilers of the same make are being set up at Sorachi for the shaft. The length of the underground levels and table of the output is as follows:—

THE LENGTH OF LEVELS.

	Sorachi Mine.	Yubari Mine.	Poronai Mine.	Ikushunbetsu Mine.
Main levels	2,033 ft. (tunnels).	267 ft. (incline).	3.389 ft. (tunnels).	——
Levels along the seams	20,864 ft.	7,904 ft.	50,654 ft.	16,876 ft.
Total	22,897 „	8,171 „	34,043 „	16,876 „

QUANTITIES OF COAL HITHERTO EXTRACTED.
(*IN TONS*).

	Poronai Mine.	Ikushunbetsu Mine.	Sorachi Mine.	Yubari Mine.	Total.
1881	838.63	—	—	—	838.63
1882	3,676.76	—	—	—	3,676.76
1883	17,301.25	—	—	—	17,301.25
1884	31,684.03	—	—	—	31,684.03
1885	36,106.00	—	—	—	36,106.00
1886	80,513.76	—	—	—	51,083.76
1887	62,692.80	—	—	—	62,692.80
1888	63,526.489	2,081.91	—	—	65,608.399
1889	77,238.40	33,047.388	—	—	110,285.788
1890	119,287.611	41,376.272	—	—	160,663.883
1891	173,661.989	54,585.867	114,407.274	—	342,655.130
Total	637,097.719	131,091.437	114,407.274	—	882,596.430

The cost of mining coal was on an average 1.172 *yen* last year (1891).

Transportation :—Transportation, both underground and on the surface, is carried on by means of wooden wagons running on tramways, which are either double or single as the case requires. The gauge is 50 cm. The rails are of steel weighing 12 pounds per yard.

The wooden wagons the frames and wheels of which are made of cast iron, are moved by hand power.

The coal is taken out from the mines in the wagons described above, and put into special store houses erected near the railway stations. The distances from the mines to the stations vary from a short distance to one mile. From the stations the coal is taken in cars (the capacity of one car averages 7½ tons) to Otaru and Muroran both of which rank with all other ports in Hokkaidō except Hakodate, thence it is sent in ships to Hakodate, Yokohama, Kōbe, Shimonoseki, Nagasaki etc.; also to Sado, Niigata, Tsuruga, etc.; so that wherever there are railroads or steamships within the limits of the Empire, there coals from these mines are seen. The coal is also sent to foreign markets the principal of which are Shanghai, Hongkong, Singapore, Manilla, the Hawaiian Islands, etc.

ATOSANOBORI SULPHUR MINE.

Situation:—The Atosanobori Sulphur Mine is in Kushiro Village Kawakami-gōri Kushiro Province, Hokkaido, about 40 miles south-east of the sea port town of Abashiri in Kitami and 56 miles north of Port Kushiro, in lat. 43° 36′ 58″ north and long. about 144° east. It is an augite andesite mountain, conical in shape, being 1600 feet above the sea level. On the northern side it is open and looks down upon a plain covered with lava and shut in by the walls of the old crater on the other sides. Sulphur is found in different parts of these walls in massive heaps. The sulphur fumes issue almost everywhere about the mine.

General History:—There is a body of water called Lake Kushiro about 3 miles north-west of the mine. It is the source of the Kushiro River. On its banks the Ainos have lived from very early times. The existence of sulphur was perhaps familiar to them at an early date.

Somewhere between 1865 and 1868, the functionaries of the Matsumaye clan are said to have worked the mine, but no trace of it can be seen now. In 1872, Sano Magoemon, an inhabitant of Kushiro heard of this mine was sent to Kushiro to inquire about it. The mission succeeded in reaching its destination by the guidance of the Kushiro Ainos. In 1876, he made some trial work, and the year following he leased some forty two acres of the sulphur mine and began regular working. He transferred the lease to Yamada Sakurō in 1885 who in turn gave it to Yasuda Zennosuke three years later. Yasuda enlarged the claim and it is now some 222 acres.

In 1877, when work was first started, the number of miners and officers was respectively thirty and five. Refining works were set

up at the mine; and the annual produce from that year to 1882 was 1,000 to 3,000 *koku*. In 1883 roads were repaired, the number of officers and miners was increased, and the produce was increased to 10000–20000 *koku*. This was, however, by no means satisfactory to the managers. So they introduced further improvements in various departments of work. In 1887, a steam refiner was set up at Hyōcha which is very conveniently situated as to the utilization of water power. A railroad was built in the same year from the mine to the Hyōcha new refining works which are 25 miles distant. The sulphur refined at Hyōcha is taken 31 miles to Port Kushiro in Japanese junks down the Kushiro River. These junks are towed by tug-boats on their return trip.

The executive department of the mining work was made systematic by the establishment of the following offices: The Central Office at Hyōcha, Branch offices at Kushiro and Hakodate, and the Mining Office at the mine.

The annual produce has been increased over 100,000 *koku* since 1888. In 1889 the railroad above mentioned was lengthened by over two miles, and the railroad, which was built for the exclusive use of the mine, will be opened for general traffic in the near future, it having been lately sold to a railroad company for that purpose.

Geological Formation:—This mine has not yet been fully surveyed geologically. According to the investigations of the Hokkaidō Chō, it is augite andesite. The adjacent places are covered with volcanic lava. Vegetation is quite luxuriant here and there, but no large trees are seen.

Ores:—The ore mined from 1877 to 1291 amounted to 726,800 *koku*; 78,300 *koku* from 1877 to 1886 and 648,500 *koku* from 1886 to 1891 inclusive. The ore may be divided into more than ten sorts, but in actual practice it is classified into only four classes as follows;

Special class containing more than 90 % of sulphur.
First „ „ „ „ 75 % „ „
Second „ „ „ „ 50 % „ „
Third „ „ „ „ 35 % „ „

Of the whole quantity of ore hitherto extracted about
10 % belonged to the Special Class,
35 % to the First,
40 % to the Second,
15 % to the Third.

The following is the average composition of the various grades.

Ore.	Sulphur.	Ash.	Water.
Special Class	9467	484	0,49
First „	8000	1,847	1,54
Second „	6000	3,823	1,77
Third „	4250	5,548	2,02

The average percentages of sulphur extracted are as follows :

	Special Class.	First Class.	Second Class.	Third Class.
New Method	80	60	50	35
Old „	75	55	40	Not Worked.

The Refining Works :—The refining works are situated at Hyōcha, 25 miles due north of the mine and 31 miles south of Port Kushiro. They were built in 1887 and often enlarged and otherwise improved afterwards, and cover at present nearly half an acre of ground and embrace an ore storage, an engine house, another house wherein condensing boxes are kept, and another where sulphur is temporarily stored before shipping.

There are two steam distillators. In connection with them there are other machines, Donkey pumps, etc. Each distillator receives four tubfuls of ore. After being charged, the distillator is closed tight and heated under fixed pressures (70 to 80). After a time varying from 50 to 90 minutes in accordance with the seasons and the qualities of ore, the sulphur is fused. It is then made to flow down into a tank placed directly under the distillator. From the tank the liquid sulphur is allowed to flow into condensing boxes through iron pipes. When the sulphur has all flowed into the boxes, the steam is withdrawn and the tubs are taken out. The tubs are then turned about and shaken to remove the refuse sulphur remaining in them. Ashes and sand which come out together with the steam are removed by means of a current of water made to run under the tank above mentioned, thus sparing a vast amount of labor which would otherwise be indispensable. The sulphur is raked out as it condenses and sent to be packed and shipped. The work is very conveniently and economically carried on, as refining, packing, and shipping places are situated contiguously.

The old method of working ores was this :—the ore was heated in a cast-iron kettle over a wood fire; the fused mass was then put into another kettle in which the impurities were allowed to sink; after which the sulphur was ladled into buckets; which were then unhooped and the sulphur was taken out, when it became quite hard. The work for carrying out these processes was performed at the mine and produced over 400 ***koku*** per day, since 1888 in which year they were greatly improved. It was therefore only on account of the remarkable superiority of the present method with regard to the percentage of extraction and general expenditure that they were abandoned in 1889.

A short time after the old works had been abandoned, a part of them was appropriated to the carrying out of the roasting process, which came to be pursued for the refuse unavoidably produced under the old system which was found to have accumulated to the enormous amount of 80,000 *Koku*, and contained 60 to 85 % of sulphur and to

yield upon roasting 40 to 65 % of it. The method of working does not essentially differ from that pursued in Kiushiu and is probably not worth while describing here.

Production Statistics:—From 1877 to 1887 the produce was comparatively small owing to the small scale of work and the inadequateness of the means of transportation, as seen in the following table.

From 1877 to 1879	Less than 100 *koku*.
„ 1880 „ 1882	About 100 „
„ 1883 „ 1886	6,000 to 10,000 „

In 1887 the produce suddenly rose to over 27,000 *koku* in consequence of the improvements in various departments of work introduced as above stated. The year following saw the introduction of steam distillators and with it a very remarkable increase of the produce. The production statistics from 1877 to 1891 are as follows:—

	Steam Works.	Roasting.	Old Works.	Totals.
1877 to 1886	—	—	51,200	51,200
1887	—	—	27,309	27,309
1888	28,988	—	40,822	69,810
1889	62,776	1,831	6,255	70,862
1890	69,072	14,499	—	83,571
1891	64,770	10,891	—	75,661
	225,606	27,221	125,586	378,413

Since 1888 the production would have increased considerably more than is seen in the above table, if it had not been the main object to work inferior ores from an economical point of view, and unless they had been regulated by the law of demand and supply.

Transportation:—The present method of transportation is this: the ore is carried down from 600 to 4,000 feet from the different parts of the mine to the station in tubs each about 2.5 *koku* capacity and drawn by one laborer, whence it is taken to Hyōcha by train. At Hyōcha it is packed and sent out to Kushiro in Japanese junks. Kushiro is the nearest port to the mine.

When work was started the ore was put into straw bags, each of 135 *kwamme* capacity. These bags were carried on horses, where the grade was not considerable, and on sleds, where horses could walk without difficulty. In 1886 wooden roads were constructed, where the ashes were very deep and the grade was great, and the bags were abandoned and tubs each 35 *kwamme* capacity used. The laborer was paid by the number of tubs he carried. The consequence was that the laborer was only anxious to carry as many tubs as he could, not caring whether the roads were bad or the ore broken or lost.

In 1889 tubs of a new fashion were introduced. The laborers were made responsible for the damage they caused to the roads. Their wages were now reckoned not upon the number of tubs, but upon the quantity of ore in weight. Since then not a piece of ore has been seen on the road and the quantity of ore each laborer carries has doubled. Under the new system the laborers are glad, for they can carry more and gain more, and the managers are pleased for they can have the same amount of work done by a far less number of laborers well-paid and satisfied, to say nothing of the loss of ore they had formerly incurred from the laborers, struggles to carry as many tubs as they possibly could. The transportation of ore from the mine to Hyōcha was at first very difficult. A narrow road was made through dense woods and by it ore was transported in straw bags, each 135 *kwamme* capacity, on horses. In 1880 the

road was repaired and the Kushiro river was utilised for the purpose of transportation. But since freshets too often came to cause work in road repairs and also since what horses and small junks could do was by no means considerable, the railroad above mentioned was built in 1887 and later lengthened by over two miles around the hill; so that ore could be taken into cars from different parts of the mine. This made it easy to transport about 200,000 *koku* per year. The rails used weigh 25 lbs. to the yard. The gauge is 3 feet 6 inches. The main line measures 25 miles 3,890 feet and the branch line 2 miles 3,860 feet. On this railway two locomotives and twenty-two cars each four tons in capacity are used.

Up to 1886 junks of from 50 to 100 *koku* capacity were used. They sailed down the river easily, but on returning they had to be towed by men and it took them 5 to 7 days going to Kushiro and back to Hyōcha although much was done in fashioning the junks to new contrivances and in dredging the river. They did not suit for the transportation of any great quantities of sulphur. So in 1887 new junks of two kinds were made; the larger ones 120 *koku* capacity for the lower part of the river, and the smaller 60 *koku* for the upper part of it, and tug-boats were introduced. This halved the number of days required for the journey. Since then about 450 *koku* of sulphur have been daily carried to Kushiro by means of thirty junks and two 6 horse power steamers.

Our Staff:—When work was started, there were only 5 officers and 30 miners. These were increased year after year, and in 1886, there were 14 officers and 70 miners, though the business did not make proportional progress. In 1887 the growth of business in the several directions referred to in the foregoing pages, necessitated the services of 43 officers and and over 700 miners. In 1889 the number of employés was lessened owing to the better management of work. The next year the development of the coal business and the construction of the tramway necessitated an increase of officers and laborers and the staff consists of the following members at present :—

Director	1.
Managers	4.
Engineers	3.
Clerks	9.
Chief Miners	3.
Captains	2.
Conductors	2.
Common Laborers	580.

The Harutori Coal Mine:—The development of sulphur refining work in 1887 made it necessary to buy about 2,000 tons of coal per year from Poronai for running the steam distillators, locomotives, and steamers. This quantity of coal could be had for no small figure in consequence of the want of an easy means of transportation. While labouring under this difficulty a coal mine was discovered, 2 miles south-east of Kushiro. The coal was found, upon examination, not to be of the best quality, but, what was highly agreeable, to contain only a small percentage of sulphur, a virtue of coal making it fit for use in boilers. As it was, some 292 acres of the coal field were leased in 1889 and worked for furnishing the sulphur industry with the coal needed. This object was more than attained, for the new mine has not only made it unnecessary to buy any more coal for the sulphur industry, but has been so prosperous as to show a surplus since 1890, which the steamers in the harbour of Kushiro have bought and buy only too gladly. Two drifts were newly opened in 1890 with railways in them. The mouths of the pits look out on Lake Harutori. The coal is taken first to the opposite or western shore of the lake in small junks and thence to Kushiro on a tramway. This tramway was constructed in 1890 and runs upwards of 7,000 feet from the western shore of the lake to the pier at Kushiro. The mine now produces 20 to 30 tons of coal per day.

Markets:—The nearest markets are Kushiro and Hakodate. The former situated 56 miles from the mine and 31 miles from

Hyōcha, is a town of about 800 houses, having hospitals, schools, a post and telegraph office, a lighthouse and the local office. Almost all articles of daily use can be had in this town. It has been made a "Special Export Town" by an Imperial decree in 1890 and therefore our products can be sent direct from it to foreign ports.

IWAONOBORI SULPHUR MINE.

Situation :—The Iwaonobori sulphur mine is at Iwaonobori, Nisekotan, and Nisekoanbetsu, Abuta-gōri, Iburi Province, Hokkaidō.

General History :—The main points under this head are: somewhere between 1854 and 1860, a Tsunemi of the Bakufu or Shogunate Government when rambling about Iwaonobori saw old pots, which seemed to him to have lain idle for many years. It has not been ascertained by whom and when they were employed.

June 1876.—Mr. Tamura Genin, a member of the Usu Einensha, discovered the Nisekotan and Nisekoanbetsu mines.

March 1879.—The Einensha commenced to work the two mines which Mr. Tamura had discovered.

February, 1877.—Messrs. Idzumi Tōbei and Murata Komakichi of Hakodate commenced mining work at Iwaonobori.

February, 1880.—The Iwaonobori mines were transferred to the Einensha.

February, 1886.—All three became the property of the Mitsui Production Company.

Preparation :—The refining works are at both Nisekoanbetsu and Iwaonobori.

The Einensha people and the lessees before them used old melting pots.

The Mitsui Production Company have introduced a steam distillator manufactured in Tokyo, two steam boilers each 12 horse-power, and six retorts. The sulphur purified and fused is suffered to flow out.

Work is annually suspended from November to April on account of snow. The present yield from May to October inclusive is 1,500 tons, which is reasonably hoped to continue for twenty years to come.

Markets and Transportation :—Exporting is the chief end. The principal markets are San Francisco and New York.

Transportation is carried on by means of horses and steamers.

Composition :—

Water	0.039 %
Sulphur	99.883 „
Ash	0.078 „

ICHIBISHINAI SULPHUR MINE.

Situation:—The Ichibishinai sulphur mine is at Ichibishinai, Betoka Village, Kunashiri-gōri, Chishima.

General History:—About 1878 Kikuchi Matsugoro of Tomari village, Kunashiri-gōri, observed fumes rising from several spots in the Ichibishinai mountain while travelling along the western coast of Hokkaidō. Upon investigation these fumes proved to be from sulphur. Kikuchi commenced to work the sulphur mine in company with Ebisu Ginzō of Nemuro, but ere long transferred it to Isobe Eiichi of Tokyo.

July 1886.—The Mitsui Production Co. became the new lessees.

Preparation:—The refining works are at Motoyama, Ichibishinai.

Improved working was commenced in 1889. The mechanical appliances used are similar to those of the Iwaonobori mine.

Production Statistics:—At present the annual yield is over 1,900 tons. This will not decrease for ten years to come.

Transportation:—Under this head the description is the same as that of the Iwaonobori mine.

Composition:—

Water	0.052 %
Sulphur	99.916 „
Ash	0.032 „

OSOREZAN SULPHUR MINE.

Situation:—The Osore-zan sulphur mine is at Osore-zan Tanabe Village, Shimokita-gōri, Mutsu Province, Aomori Prefecture.

General History:—The date of discovery is unknown. It was opened for the first time in 1885 by Tachibana Ikuji. In 1888 it came under Matsuoka Yuzuru and later under the Mitsui Production Company, the present lessees.

Preparation:—Before the Mitsui Production Company's time the methods pursued were purely Japanese. Now they use an 8 horse-power steam-boiler and 4 retorts.

Production Statistics:—Over 800 tons per year. This will continue for eight years to come.

Of transportation and markets the description is the same as that of the Iwaonobori mine.

ARAYU SULPHUR MINE.

Situation :—The Arayu sulphur mine is at Arayu, Onikōbe Village, Tamatsukuri-gōri, Rikuzen Province, Miyagi Prefecture.

General History :—The discoverer is unknown. This mine was under Yusa Tomoji from about seventy years ago, till 1887 when the Mitsui Production Company had it transferred to them.

Preparation :—The native sulphur is distilled in pots, liquified in condensing rooms, and suffered to flow out. The pots of which there are twelve are all built of brick.

Production Statistics :—The annual yield is 750 tons. This will continue for ten years more.

Transportation and Markets :—The sulphur of this mine is all sold at home. The modes of transportation from the mine to Yokohama, the central market, are as follows :—

To Kajigasawa............... 8½ miles by horses and oxen.
,, Komoda.................. 23 ,, ,, horse wagons.
,, Tokyo or Yokohama........................train.

Refining Works :—The refining works are at Motoyama in Arayu.

AMAZE PETROLEUM WELLS.

Situation:—The Amaze Petroleum Wells are in Amaze and Katsumi, Amaze Santo-gōri, Echigo, Niigata Prefecture. The Office and the mill stand on a piece of land about the wells made by filling up the sea.

General History:—Oil drops have been observed from time immemorial at several spots in the sea within six hundred feet of the land part of this claim. The ancients called the oil *Kusozu abura*, i.e. stinking oil. At one time the poor people gathered it by means of straws for use in lighting purposes, but before long a superstitious idea that its odor might offend the taste of their tutelary god dissuaded them from doing so.

From about 1872, people commenced again to pay attention to this oil and several attempts were made to get it by sinking wells upon eminences near the sea-shore, but none of them produced paying results. In 1882 or 1883 several of the inhabitants of Amaze established a joint-stock company and obtained a lease for a few hundred *tsubo* on the coast. They sank wells and obtained some oil, sometimes in pretty large quantities, as at one time in 1886, when they obtained nearly twenty *koku* per diem for several successive days and enjoyed a high degree of prosperity. But these persons, as too many similarly engaged in many other places, were mere speculators having no public interest or permanent business in view; and allowing themselves to be taken by lucre from one place to another. This character of theirs in time made the business itself detestable in the eyes of respectable persons.

Meanwhile the yearly increase of the importation of foreign oil weighed heavily upon the minds of thoughtful persons. In February,

1888 Yamaguchi Gonzaburō, Naitō Hisahiro, Makiguchi Shōzaburō, Honma Shinsaku, and others came forward as pioneers in this field of enterprise and established a company called "the Japan Petroleum Company" with a capital of 150,000 *yen*. They leased their preseut claim in the same year.

Before starting the business they had had a mining engineer sent from the Agricultural and Commercial Department for their adviser. His advice and their own designs got them fairly started, but their means of making wells being mainly of the old manual nature, could not enable them to push down to more than six or seven hundred feet.

The year following, it happened that Yamaguchi Gonzaburō went abroad on a tour of industrial observation. The Company had him investigate the ways in which they use drilling machines in America. This resulted in:

1. Buying drilling machines made by the Pierce Artesian and Oil Well Supply Company of New York.
2. Actually using them from Dec. 1890.
3. Sinking three wells 800 to 1,000 feet deep.
4. These wells commencing to yield oil with remarkably promising results.
5. Sending for an engineer to the said Pierce Company.

It is to the Japan Petroleum Company that one should give the credit of having started the petroleum business in Japan in anything like a respectable manner. This company has improved American machines so as to be capable of sinking wells over 2,000 feet deep. The business presents very bright prospects.

Sinking Wells:—The old method of sinking a well is mainly manual. The ground is dug four feet square for several tens of feet and afterwards a square foot less. The walls are enclosed with planks to prevent the well from caving in. The depth they can reach thus is six to seven hundred feet. The tools used are picks, spades,

pulleys, buckets, pails, rope-baskets, bellows, a set of carpenter's tools, and one of black-smith's.

When the work is started only three or four laborers are employed per diem. Their number is gradually increased as the sinking progresses and about the time the well is 600 feet deep no less than twenty are usually employed. The work goes on at the rate of about two feet per diem. The worker in the well enters it twice in the morning and as often in the afternoon, remaining there for two hours each time. The air is constantly sent in to him by means of a bellows and a wooden pipe. This method is resorted to with only the shallower wells. The deeper ones are sunk by means of American machines.

Geology:—The rock is a soft sandstone, light brown in color.

The oil-bearing strata run in the form of a saddle extending from the north-east to the south-west, Those on the south-east side extend toward the Betsuyama district and those on the north-west into the sea. The present claim includes both of them and those at present worked run toward the north-west from the highest point of the saddle.

The strata dip twenty degrees or thereabouts.

The richness of the strata is proportional to their depth.

Depth of Wells:—The shallowest is 90 feet and the deepest 1,000 feet. The latter is still being drilled deeper.

Expenses:—The annual working expenses are about 20,000 *yen* and a similar sum is spent in buying machines, pipes, etc.

Refining:—Before the Restoration, the oil was simply distilled in rude stills and no chemicals were used in its treatment. It was since that memorable epoch in Japanese history that people turned their attention to improving the refining processes after the American methods. Our refining processes are as follows:

A still is filled two-thirds full with the crude oil and heated. As the oil is heated the vapor produced rises into a pipe made cold

by proper contrivances and drops out of the outer end of the pipe. The fixed temperature is 15.5 degrees C.

The oil above 60° B, in density is the *volatile oil.* That of 35 to 60° B. is the *lamp oil.* That below 35 degrees B. is the heavy oil.

To remove the disagreeable odor of the lamp oil, it is poured into a pail after being well stirred up. A quantity of sulpuric acid is added and the mixture briskly stirred. On setting the sulphuric acid is drawn by turning a screw in the bottom of the pail. The oil is then washed in warm water, next in caustic soda and then in warm water again. The result is pure transparent oil.

Fuels:—Any quantity of wood and charcoal can be easily obtained at reasonable rates.

As the claim is situated on the sea coast coal is easily obtainable from Hokkaidō.

More than half of the fuel needed is supplied by the natural gas from the wells. It is expected that by this gas we shall be able to dispense with the use of all the other kinds of fuel.

Production Statistics:—The produce since starting our business in 1888 is as follows:—

1888	578.33 *sho.*
1889	4,522.36 ,,
1890	5,227.97 ,,
1891	5,076.49 ,,
1892 (till Nov.)	5,920.23 ,,
Total	21,325.38 *sho.*

Transportation:—The oil is taken from the wells into a reservoir. From the latter it is made to flow to the mill in 2-inch iron pipes.

The refined oil is sent to markets both by sea and land.

Percentage of Extraction:—The crude oil worked usually produces 85 % of the lamp oil and of the remaining 15 % 12 is devoted to paraffine making, and 3 is lost.

The crude oil is 38 to 43 degrees *B.* in density and that of the refined, 43 degrees *B.*

The producc of these wells is of the best quality and is excelled by none produced in any other place in Japan.

Cost of Manufacture :—The cost of labor, chemicals, etc. is 4 *yen* per 10 *koku.*

The vessels cost 30 *sen* per 2 *to.*

Power :—The steam power used at present is as follows ;

3–20 Horse power Portable boilers.
2–10 „ „ „ „
3–15 „ „ Reversible ring engines.
2–10 „ „ „ „ „
4 Drilling machines.

Markets :—The principal markets in Niigata Prefecture are Niigata and Nagaoka, to the former of which it is 38 miles and to the latter 17.

The different ports of the northern provinces and Hokkaidō arc easily accessible.

STATISTICS OF THE PRODUCTION OF GOLD IN THE YEAR 1890.

Name of Mine.	Province.	Prefecture.	Quantity in *Momme.*			
			From Gold Mining.		Form Gold Washing.	Total.
	Shiribeshi	Hokkaidō	—	—	366	366
	Mutsu	Aomori	—	277	—	277
	Rikuchiū	Iwate	3,228	8,569	—	8,569
Kurihashi	„	„	5,341			
	„	Akita	3,436	21,919	—	21,919
Komaki	„	„	18,483			
	Ugo	„	5,124	9,632	—	9,632
Okudzu	„	„	4,508			
	„	Yamagata	—	—	103	103
	Uzen	„	—	804	221	1,025
	Rikuzen	Miyagi	—	1,076	103	1,179
	Iwashiro	Fukushima	3,678	10,750	1	10,751
Handa	„	„	7,072			
	Hitachi	Ibaragi	—	724	—	724
	Musashi	Saitama	—	343	—	343
	Kōdzuke	Gumma	—	73	—	73
	Echigo	Niigata	941	61,521	—	61,521
Sado	Sado	„	60,580			
	Kai	Yamanashi	—	280	249	529
	Suruga	Shidzuoka	23	149	—	149
	Idzu	„	126			
	Hida	Gifu	—	—	502	502
	Kaga	Ishikawa	127	5,530	116	5,646
Kanahira	„	„	5,403			
	Echizen	Fukui	—	305	—	305
	Harima	Hiōgo	108	7,001	—	7,001
Ikuno	Tajima	„	6,893			
	Iyo	Ehime	—	—	71	71
	Bungo	Ōita	83	117	—	117
	Buzen	„	34			
	Hiuga	Miyasaki	—	579	—	579
	Ōsumi	Kagoshima	—	—	22,514	22,514
	Satsuma	„	3,674	—	7,573	7,573
Serigano	„	„	4,534			
Yamagano & Nagano	„	„	18,687	32,294	—	32,294
Kago	„	„	5,399			
				161,943	31,819	193,762

193,762 *momme* = 23,401 ozs.

STATISTICS OF THE PRODUCTION OF SILVER IN THE YEAR 1890.

Mine.	Province.	Prefecture.	Quantity in *Momme.*	
	Mutsu	Aomori	——	540
	Rikuchiū	Iwate	——	16,676
Innai	Ugo	Akita	3,001,827	
Ani	"		710,915	
Towada	Rikuchiū		163,758	
Kosaka	"		1,806,718	
Komaki	"		628.347	
Omaki	Ugo		680,155	
Hata	"		88,111	
Midzusawa	"		70,223	
Hakusan	"		111,025	
Hanaoka	"		40,606	
Iwanome	"		197,469	
Matsuoka	"		248,050	
Nakagawa	"		37,744	
		Akita	235,423	8,020,371
Mayeyama	Ugo.	Yamagata	37,800	
		Yamagata	31,900	69,700
Karuizawa	Iwashiro	Fukushima	821,915	
Handa	"	"	421,700	
Takatama	"	"	16,288	
		Fukushima	31,987	1,291,890
Kanayama	Shimotsuke	Tochigi	81,726	
Toyooka	"	"	59,103	
		Tochigi	2,152	142,981
Sado	Sado	Niigata	988,883	
Otaniyama	Echigo	"	46,512	
		Niigata	25,999	1,061,394
Kamioka	Hida	Gifu	1,092,120	
Hadasa	Mino	"	206,301	
Kurokawa	"	"	26,680	
		Gifu	25,988	1,351,089

STATISTICS OF THE PRODUCTION OF SILVER IN THE YEAR 1890.—*Cont.*

Mine.	Province.	Prefecture.	Quality in *Momme.*	
	Etchiū	Toyama	—	12,082
	Kaga	Ishikawa	—	4,136
Omodani	Echizen	Fukui	327,130	
Nakatenjio	,,	,,	66,650	
Okunakayama	,,	,,	33,991	
		Fukui	82,061	509,832
	Tamba	Kiōto	—	41,187
	Settsu	Ōsaka	—	25,894
Ikuno	Tajima	Hiōgo	865,154	
Makinoshinmachi	Harima	,,	18,565	
Motomizuka	Tajima	,,	104,277	
Kuratoko	Harima	,,	37,707	
	Settsu, Tamba, etc.	Hiōgo	155,035	1,180,738
	Iyo	Ehime	—	4
	Mimasaka	Okayama	—	6,865
Sasagatani (1)	Iwami	Shimane	4,664	
,, (2)	,,	,,	54,217	
		Shimane	2,597	61,478
Okaoku	Bingo	Hiroshima	11,228	
	Aki and Bingo	Hiroshima	12,711	23,939
	Suwō and Nagato	Yamaguchi	—	20,865
	Bungo	Oita	—	140
Yamagano and Nagano	Satsuma	Kagoshima	11,235	
Serigano	,,	,,	11,666	
Kago	,,	,,	3,998	
Kohira	,,	,,	45,003	
Sekitoan	,,	,,	36,600	
		Kagoshima	141,454	249,953
				14,091,754

14,091,754 *momme* = 1,701,903 ozs.

STATISTICS OF THE PRODUCTION OF COPPER IN THE YEAR 1890.

Mine.	Province.	Prefecture.	Quantity in Piculs.	
Okoshinai	Shiribeshi	Hokkaidō	—	482
	Mutsu	Aomori	—	111
Yuda No. 1	Rikuchiū	Iwate	1,744	
„ No. 2	„	„	695	
Yusawa	„	„	540	
Midsusawa	„	„	379	
	„	Iwate	1,979	5,337
Ani	Ugo	Akita	11,646	
Kosaka	Rikuchiū	„	1,165	
Arakawa	Ugo	„	16,021	
Komaki	„	„	3,352	
Nakagawa	„	„	980	
Towada	Rikuchiū	„	898	
Furokura	„	„	1,552	
Hosoji	„	„	469	
Daira	Ugo	„	207	
	„	Akita	7,528	43,818
Shachiu	Ugo	Yamagata	709	
	Uzen	„	618	1,327
Nishikamo	Rikuzen	Miyagi	428	
	„	„	105	533
	Iwashiro	Fukushima	—	335
Ashio	Shimotsuke	Tochigi	97,062	
Kidogasawa	„	„	573	
Daimiosawa	„	„	549	
	„	„	153	98,337
	Kōtsuke	Gumba	—	23
Kusakura	Echigo	Niigata	9,715	
Hirotani	„	„	2,080	
Akadani	„	„	338	
Mase	„	„	312	
	„	„	782	13,227

STATISTICS OF THE PRODUCTION OF COPPER IN THE YEAR 1890.—*Cont.*

Mine.	Province.	Prefecture.	Quantity in Piculs.	
	Shinano	Nagano	——	16
Minenosawa	Tōtōmi	Shizuoka	781	
	"	"	204	985
Kamioka	Hida	Gifu	625	
Torikiriyama "	"	"	651	
Obora "	"	"	926	
Hadasa	Mino	"	323	
Kurokawa	"	"	373	
	Mino and Hida	"	415	3,313
	Etchiū	Toyama	——	109
Ogoya No. 1	Kaga	Ishikawa	10,765	
" No. 2	"	"	498	
Ate	"	"	4,011	
Yusenji	"	"	910	
	"	"	920	17,104
Omodani	Echizen	Fukui	4,652	
Nakatenjō	"	"	673	
	"	"	1,012	6,337
Murogaki	Tamba	Kiōto	580	
Takatani	"	"	274	
	"	"	530	1,384
	Settsu	Ōsaka	——	424
	Ise	Miye	——	135
Tateri	Yamato	Nara	3,419	
Kuroishi	"	"	421	
Hiura	"	"	421	
Akakura	"	"	339	
	"	"	2,498	7,098
Kouchibira	Kii	Wakayama	1,558	
Kudoyama	"	"	805	
	"	"	1,151	3,514

STATISTICS OF THE PRODUCTION OF COPPER IN THE YEAR 1890.—*Cont.*

Mine.	Province.	Prefecture.	Quanlity in Piculs.	
Makinoshinmachi	Harima	Hiogo	641	
Ikuno	Tajima	"	223	
Kabasakayama	Harima	"	374	
Kurusuyama	"	"	378	
	Harima, Tajima and Settsu	"	1,787	3,403
Higashiyama	Awa	Tokushima	774	
Kawamata	"	"	321	
	"	"	318	1,413
Kanayama	Tosa	Kōchi	699	
Nakamine	"	"	497	
Furuidani	"	"	318	
	"	"	1,352	2,866
Besshi	Iyo	Ehime	30.571	
Ose No. 1	"	"	1,727	
" No. 2	"	"	553	
Saredani	"	"	2,618	
Noji	"	"	440	
	"	"	917	36,826
Yoshioka	Bitchiu	Okayama	8,592	
Kokusei	Mimasaka	"	3,603	
Waidani	Bizen	"	649	
Yatakayama	"	"	749	
Konshozan	Mimasaka	"	784	
Kanahoriyama	"	"	408	
Katayama	Bitchiu	"	478	
Sunaba	"	"	430	
		"	2,782	18,475
		Tottori	—	143
Sasagatani No. 1	Iwami	Shimane	6,201	
" No. 2	"	"	432	
Dogamaru	"	"	2,373	

STATISTICS OF THE PRODUCTION OF COPPER IN THE YEAR 1890.—*Cont.*

Mine.	Province	Prefecture.	Quantity in Piculs.	
Toishi	Iwami	Shimane	749	
Okanayama	"	"	566	
Adakai	Izumo	"	817	
Udo	"	"	424	
		"	380	11,942
Okaoku	Bingo	Hiroshima	701	
Mayeichiyama	"	"	348	
	Aki and Bingo.	"	904	1,953
Dzomeki	Nagato	Yamaguchi	2,400	
Negasa	"	"	284	
Idenooku	"	"	511	
	Nagato and Suwō	"	1,140	4,335
Iwaya	Higo	Kumamoto	1,499	
Itsuki	"	"	942	
	"	"	259	2,700
Nishidaninishi	Bungo	Oita	643	
Otsurumidzu No. 1.	"	"	907	
" No. 2.	"	"	218	
	"	"	10	1,778
Hibira	Hiūga	Miyasaki	9,370	
Makimine	"	"	1,216	
	"	"	187	10,773
	Satsuma and Ōsumi	Kagoshima	—	382
Hajimakiri	Riūkiū	Okinawa	—	986
				301,924

STATISTICS OF THE PRODUCTION OF COPPER SULPHATE IN THE YEAR 1890.

Mine.	Province.	Prefecture.	Quantity in Piculs.
Ashio Copper Mine.	Shimotsuke	Tochigi	452

STATISTICS OF THE PRODUCTION OF LEAD IN THE YEAR 1890.

Mine.	Province.	Prefecture.	Quantity in Piculs.	
	Mutsu	Aomori	—	7
	Rikuchiū	Akita	183	
Komaki	”	”	3,143	
	Ugo	”	820	
Nakagawa	”	”	332	
Ani	”	”	103	
Daira	”	”	759	5,340
	Rikuchiū	Iwate	138	
Uda	”	”	962	1,100
	Iwashiro	Fukushima	—	199
	Echigo	Niigata	—	203
	Shimotsuke	Tochigi	189	
Toyooka	”	”	612	801
	Hida	Gifu	208	
Kamioka	”	”	2,622	2,830
	Echizen	Fukui	646	
Nakatenjio	”	”	718	1,364
	Tamba	Kiōto	—	12
	Harima	Hiōgo	43	
	Settsu	”	22	
	Tajima	”	104	169
	Mimasaka	Okayama	42	
	Bitchiū	”	778	820
	Bingo	Hiroshima	—	16
	Suwō	Yamaguchi	40	
	Nagato	”	7	47
	Bungo	Oita	—	5
				12,913

STATISTICS OF THE PRODUCTION OF TIN IN THE YEAR 1890.

Mine.	Province.	Prefecture.	Quantity in Piculs.
	Bungo	Oita	158
	Hiūga	Miyasaki	35
	Ōsumi	Kagoshima	69
Taniyama	Satsuma	"	354
Nakatsugawa Stream tin.	Mino	Gifu	175
			791

STATISTICS OF THE PRODUCTION OF ANTIMONY IN THE YEAR 1890.

Mine.	Province.	Prefecture.	Quantity in Piculs.	
	Uzen	Yamagata	—	115
	Shimotsuke	Tochigi	—	262
	Echizen	Fukui	—	520
	Yamato	Nara	826	
Sodani	"	"	120	946
	Tosa	Kōchi	—	3,211
	Iyo	Ehime	2,355	
Ichinokawa	"	"	25,224	
Kawanobori	"	"	961	28,540
	Bitchiū	Okayama	—	49
	Iwami	Shimane	—	420
	Nagato	Yamaguchi	19	
	Suwō	"	2,317	
Kanokami	"	"	15,960	18,296
	Higo	Kumamoto	—	173
	Bungo	Oita	—	132
	Hiūga	Miyasaki	—	642
				53,306

Statistics of the Production of Arsenic in the Year 1890.

Province.	Prefecture.	Quantity in Piculs.
Rikuzen	Miyagi	564
Bitchiū	Okayama	4
Iyo	Ehime	1,304
		1,872

Statistics of the Production of Manganese in the Year 1890.

Province.	Prefecture.	Quantity in Piculs.
Ugo	Akita	442
Shimotsuke	Tochigi	12,130
Noto	Ishikawa	645
Tamba	Kiōto	28,750
Iyo	Ehime	1,224
		43,191

Statistics of the Production of Iron in the Year 1890.

	Province.	Prefecture.	Quantity in Tons.	
	Mutsu	Aomori	—	15
	Rikuzen	Miyagi	—	57
	Harima	Hiōgo	—	33
	Bitchiū	Okayama	563	
	Mimasaka	„	304	867
Form Iron Sand	Hōki	Tottori	—	3,539
	Izumo	Shimane	3,704	
	Iwami	„	3,706	7,410
	Bingo	Hiroshima	1,866	
	Aki	„	3,646	5,512
	Hiūga	Miyasaki	—	2
	Total Product from Iron Sand			17,435
From Iron Ore	Kamaishi Rikuchiū and others Rikuzen Iwate...........			4,801
	Total			22,236

STATISTICS OF THE PRODUCTION OF COPPERAS IN THE YEAR 1890.

Province.	Prefecture.	Quantity in Piculs.
Echizen	Fukui	147
Bizen	Okayama	2,684
Bitchiū	"	11,841
Bungo	Oita	1,115
		15,787

STATISTICS OF THE PRODUCTION OF COAL IN THE YEAR 1890.

Coal Fields.		Quantity in Tons.	
Miike Colliery (Fukuoka)		—	481,590
Takashima Colliery (Nagasaki)		279,890	
Nakanoshima " "		138,039	
Hashima " "		8,344	426,273
Chikuzen and Buzen coal fields (Fukuoka)	Shakanoo	51,765	
	Oguma	32,321	
	Isomitsu	23,872	
	Tsunawake	31,825	
	Shinniw	37,357	
	Kusubashi	25,889	
	Shimozakai	57,385	
	Oshiro	49,184	
	Tadakuma	25,198	
	Namadzuda	36,266	
	Mineji	12,252	
	Otsuji	48,227	
	Other collieries	349,307	780,848
Taku and Karatzu (Saga)		—	174,167
Hirado and Imabuku (Nagasaki)		—	222,250
Amakusa (Kumamoto)		—	68,768
Muro-gōri (Miye and Wakayama)		—	48,833
Shiramidzu (Fukushima and Ibaragi)		—	35,916
Aburado (Yamagata)		—	6,677
Hokkaidō	Poronai	125,993	
	Ikushunbetsu	44,464	
	Other collieries	15,761	186,218
Other provinces		—	176,744
			2,608,284

STATISTICS OF THE PRODUCTION OF SULPHUR IN THE YEAR 1890.

Mine.	Province and Prefecture.	Quantity in Piculs.
	Oshima	5,171
Atosanobori	Kushiro Kawakami-gori Kushiro	208,898
Shiratokoyoma	Kitami	21,516
Iwaonobori	Abuda-gori Iburi	26,865
Ishibishinai	Chishima	18,475
Rausu	"	15,598
	"	75,157
Osore-zan	Mutsu Aomori	2,475
	" "	639
	Rikuchiū Iwate	136
	" Akita	591
Ishikarito	Ugo Akita	12,752
	" "	1,851
	Iwaki	1,263
	Rikuzen Miyagi	44
Adumasan	Iwashiro Fukushima	8,728
	" "	4,798
	Izu Hichitō Tōkyō	5,035
	Sagami Kanagawa	6,083
	Shimodzuke Tochigi	1,070
Shiraneyama	Kōdzuke Gunma	7,783
	" "	1,672
	Echigo Niigata	37
	Shinano Nagano	42
	Etchiū Toyama	204
	Hizen Nagasaki	1,050
	Higo Kumamoto	72
	Bungo Oita	6,440
	Ōsumi Kagoshima	569
Nakashima-mura	Kawanabe-gori Satsuma Kagoshima	7,540
	Satsuma Kagoshima	184
		442,738

STATISTICS OF THE PRODUCTION OF GRAPHITE IN THE YEAR 1890.

Mine.	Province.	Prefecture.	Quantity in Piculs.
	Rikuchiū	Miyagi	1
Kawai-mura	Hida	Gifu	75,773
	Etchiū	Toyama	63
	Nagato	Yamaguchi	50
	Satsuma	Kagoshima	198
			76,085

STATISTICS OF THE PRODUCTION OF PETROLEUM IN THE YEAR 1890.

Province.	Prefecture.	Quantity in Gallons.
Ishikari	Hokkaidō	1,213
Ugo	Akita	11,400
"	Yamagata	7,341
Echigo	Niigata	1,858,950
Shinano	Nagano	45,670
Tōtōmi	Shizuoka	92,542
		2,017,116

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